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ELEMENTARY SCIENCE LESSONS

BEING A SYSTEMATIC COURSE OF

PRACTICAL OBJECT LESSONS

ILLUSTRATED BY SIMPLE EXPERIMENTS

BY

W. HEWITT, B.Sc.

SCIENCE DEMONSTRATOR FOR THE LIVERPOOL SCHOOL BOARD

STANDARD IV.

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PREFACE

The present volume contains a course of thirty-six Practical Object Lessons, systematically arranged, and designed specially for the purpose of training and developing the minds of young children, and of interesting them in an intelligent study of the facts and phenomena connected with the common objects by which they are surrounded.

It forms the fourth year's course of a system of Elementary Science Lessons (such as those contemplated by the Revised New Code), which is intended to carry the children step by step from the preliminary and general training of the lower standards to the more specialised science lessons for older scholars.

The present series of lessons might, if desired, be taken alone as a suitable introduction to a course on 'Mechanics' or 'Natural Philosophy'; but taken in connection with the other series (Standards I., II., and III.) previously published, the full course would supply not only a valuable means of intellectual training, but also a useful introduction to any further science teaching, inasmuch as it deals in a simple manner with the fundamental principles common to all branches of physical science.

The following lessons are for the most part occupied with a consideration of various important properties of bodies, and of some practical applications to which the substances possessing those properties in a marked degree are put. They also treat in an elementary manner of the instruments and units employed in simple processes of weighing and measuring. Wherever possible, the principles illustrated in the lessons are applied to explain natural phenomena and the facts of ordinary daily life.

The author can speak from a long experience of science teaching in elementary schools as to the educational value of practical object lessons, with simple experimental illustrations of the character of those sketched out in the following pages, in cultivating the intelligence of the children.

The scheme, of which the present course forms a part, was drawn up at the request of the Liverpool School Board, to meet a long-felt necessity for a continuous and connected system of practical object lessons running throughout the whole of the elementary school course and developing into the more specific experimental science teaching of the higher standards.

W. H.

LIVERPOOL: *Feb.* 1892.

CONTENTS

LESSON		PAGE
	LIST OF APPARATUS	vii
	INTRODUCTION	ix
I.	CLASSIFICATION OF SUBSTANCES	1
II.	ICE AND WATER	5
III.	SOLIDS AND LIQUIDS	9
IV.	WATER AND STEAM	13
V.	LIQUIDS AND GASES	18
VI.	PRESSURE OF THE AIR	22
VII.	A POP-GUN	27
VIII.	INDIA-RUBBER	31
IX.	ELASTIC BODIES	35
X.	A SPRING BALANCE	39
XI.	FORCE	44
XII.	THE COMMON SCALES AND WEIGHTS	49
XIII.	SAWDUST	53
XIV.	CORK	57
XV.	SPONGE	61
XVI.	POROUS BODIES	65
XVII.	THE SKIN	68
XVIII.	A CANDLE	72

LESSON PAGE
XIX. Hard and Soft Bodies 76
XX. Steel 79
XXI. Brittle Bodies 83
XXII. Straight Line and Ruler 87
XXIII. Foot-rule and Tape-measure 91
XXIV. A Square.—Area 95
XXV. A Cube.—Volume 99
XXVI. Inch, Square Inch, and Cubic Inch . . . 103
XXVII. A Pint Measure 107
XXVIII. Horizontal Surface of Liquids 111
XXIX. A Spirit Level 115
XXX. A Plumb Line 119
XXXI. A Table 123
XXXII. Moist Clay 127
XXXIII. Gold and Gold Leaf 132
XXXIV. Solids, Liquids, and Gases 136
XXXV. A Sundial 140
XXXVI. Day and Night 144

LIST OF APPARATUS

Hollow india-rubber ball, closed
Ditto, with opening
3 glass tumblers
Wax candle
Candlestick
Large cork
'Virgin cork,' piece about 12 inches × 6 inches
Moist clay
Methylated spirit (in bottle)
Sawdust
Sealing wax
Sheet of glass, about 18 inches × 6 inches
Pieces of sheet copper, sheet lead, sheet iron, and tinned plate, about 6 inches × 3 inches
Lead pipe
Treacle (in wide-mouthed bottle)
2 plates
Large glass marble
Lump sugar (in bottle)
Spirit-lamp or stove (see fig. 1, page 15), with support for kettle or dish
Matches
Iron tablespoon
Shallow tin dish, about 4 inches diameter
Glass funnel, 3 inches diameter
Slate
Benzoline (in bottle)
Strong nitric acid (in glass-stoppered bottle)
Glass bottle, 4 oz. or 6 oz. wide mouth
Square glass bottle
Jug
Sucker (of stout leather, about 3 inches diameter)
Glass syringe
Bottle, fitted with caoutchouc stopper perforated with one hole for stem of funnel. (See fig. 3, page 25)
Pop-gun. (See fig. 7, page 29)
India-rubber bands
Thick india-rubber cord
Bar of india-rubber, 4 inches × 1 inch × ½ inch
String
Table-knife
Tuning-fork
Clock-spring
Spring-balance
2 brass S-hooks
Iron weights with rings, 1, 2, and 4 lbs.
Foot rule
Two-foot rule
Spiral steel spring (fig. 10, page 41)
Pair of scales

Set of weights, flat, 1 lb. down to ¼ oz.
Sand (white, in bottle)
Pint and half-pint measures
Hammer
Sponge
Basin
Calico
Pumice stone
Brick
Salt (in bottle)
Steel file, triangular
Scissors
Large iron nail
Horseshoe magnet
Glass tube, thin
Thin copper wire
Yard rod
Tape-measure
Cardboard
Wood cube, 3 inches side
Wood prism, 3 inches × 3 inches × 4 inches
24 wood inch cubes
Glycerine (in bottle)
Plumb-line
T-square
Board, 12 inches square
Ditto with hole for rod in centre
Small brass (stair) rod
Round ruler
Book of Dutch-metal leaves
Gold-leaf, mounted between sheets of glass
Compass needle on stand
Globe

INTRODUCTION

SUGGESTIONS TO THE TEACHER

THIS fourth series of Elementary Science Lessons is drawn up on the same lines and based upon the same general principles as those underlying the three series which have preceded it. These principles have been explained in the introductions to the preceding series, and it is therefore not necessary to state them again at length. This series, like the others, consists of a course of Object Lessons systematically arranged, and dealing in great measure with facts and principles which admit, more or less, of simple experimental demonstration.

The main object aimed at in drawing up the present course has been to afford the children opportunities for observation in connection with some of the more fundamental and general properties of bodies, so as to lead them to reason about cause and effect, to compare one body with another, and as a result of such observation and comparison to generalise and to classify. While the following lessons are naturally somewhat more specialised in character than those of the preceding series, they still deal with fundamental principles which lie at the foundation of all scientific knowledge, and which are more or less common to all branches of physical science.

The order of arrangement of the lessons has been very carefully considered, so that one may naturally lead on to another; and this order should be followed as far as possible.

The simple experiments described as being necessary to illustrate the lessons will readily be understood from the descriptions given in the notes, but in several cases an illustration has been added in order to make the arrangement quite clear. The apparatus required is of the simplest character, and in many cases where the exact object mentioned is not readily accessible a suitable substitute will easily be found. The teacher should always devote some time to a careful study of the lesson, and to a preparation of the various objects required for the illustrations and experiments.

It will often happen that other illustrations and experiments besides those mentioned in the notes will occur to a good teacher in the course of his preparation; and these should, whenever possible, be introduced, provided, of course, that they are appropriate and relevant. It should, however, be clearly understood that an experiment introduced into a lesson ought always to be introduced for a definite purpose connected with the general scheme of the lesson; either to make clear some fact or statement, to suggest some new idea or obtain some new information, or to test some inference or suggestion. If the experiment fail to serve one or other of these purposes, it is worse than useless; since it distracts the attention instead of fixing it, and leads the thoughts of the pupils away from their proper course.

The children are to be led, as far as possible, to exercise original and independent thought upon the objects and experiments set before them: to state the result of their observation and thought in clear and definite, though simple, language: and to suggest means of testing and proving statements made by themselves or by others, and steps to be taken to acquire additional information. It is intended in this, as in the previous courses, that the children shall be told nothing which they can reasonably be expected to find out for themselves. If the teacher has carefully studied the lesson in advance and understands its general aim, he may find it an advantage, in some cases, to vary the arrangement of the notes as here given, in order to follow the particular line of thought which the children seem to be taking. In such cases, however, the teacher must be careful not to allow the lesson to develop into a general wide and desultory conversation; but must seek to guide the children along the main lines previously laid down, without unduly repressing the free exercise of their minds. The elasticity and freshness thus imparted to the lessons will, in the hands of a judicious teacher, add not only to the interest, but also to the value of the instruction.

The following lessons almost of necessity involve the use of a number of technical terms (that is, of special words adapted to express certain definite ideas) with reference to the properties of bodies. The fact or property which the term expresses should in all cases be first made familiar to the children by suitable illustration and the examination of typical specimens; and only after this has been done should the term be introduced and its use explained. The children might then be encouraged to use the term in their answers and statements, but there should be no attempt at this stage to teach any formal definitions.

The lessons in the following series deal for the most part with certain properties of solid bodies—

brittleness, porosity, hardness, elasticity, &c.—upo which, in many cases, the practical applications of th substances depend. The division of bodies into solids, liquids, and gases is considered only briefly in the present course, by reason of its having formed the mai subject of the lessons in the preceding course. It wil be observed that, as a general rule, before any specia property is studied, there is a lesson on some typica substance which possesses that property in a marke degree; then in a subsequent lesson it is shown tha other bodies resemble the first in possessing the sam character, and thus the abstract idea of the property i obtained. An opportunity has been taken in this cours to give the children an elementary idea of force, an the action of force upon matter; and several simpl lessons upon various processes of weighing and measuring, and the instruments and units therein employed, have been introduced, partly from a consideration of the fact that 'weights and measures' forms a part of the course of arithmetic required of children in this Standard. The paragraph at the head of the notes in each lesson will serve to show somewhat of the idea with which the particular lesson has been introduced, and its relation to others of the series.

LESSON I.

CLASSIFICATION OF SUBSTANCES.

OBJECTS REQUIRED—*India-rubber* (*ball*); *water* (*in tumbler*); *wax candle*; *cork*; *soft clay*; *methylated spirit*; *sawdust*; *sealing-wax*; *glass* (*sheet*); *copper* (*sheet or wire*); *treacle* (*syrup*); *lead*; *salt* (*on plate*).

ANALYSIS OF LESSON.

Recognise substances on table.

Substances are recognised by possession of certain characters—soap, paraffin oil.

Describe 'properties' by which various substances on table are identified.

Our means of observing properties of bodies—'senses.'

Examples of different substances having a common property.

Ex.—*Separate substances that will burn from others.*

Various bases for classification—colour, smell, solid and liquid, &c.

Ex.—*Classify substances according to various properties.*

Examples of substances belonging to named class—black substances, sweet substances, metals, foods, &c.

Examples of substances to accompany one named—butter, ice, &c.

NOTES.

Subject of Lesson.—This lesson, introductory to the course, is intended to direct attention to the means by which we distinguish one substance from another, or recognise that two bodies agree in the possession of a common property, and thus to explain and illustrate the principles which guide us generally in the classification of substances.

Have on the table a number of substances—for the most part those which will be used in the subsequent lessons of the course, e.g. india-rubber ball, water, wax candle, cork, moist clay, methylated spirit, sawdust, sealing-wax, glass, salt (on plate), copper sheet or wire, blotting-paper. Let the children recognise the substances, either as they are held up before the class, or by coming to the table.

Explain to the class that we observe some one or more facts about a substance which lead us to recognise it, and that it is usually possible to describe to others what these facts are. Illustrate your meaning by leading the children to describe several ways in which you might proceed to find out whether a piece of substance were really soap, or a certain liquid in a bottle were paraffin oil.

Then let the children describe, as far as possible, some of the characters or *properties* by which they recognise the various substances, holding some specimens up in front of the class, and giving others, such as the cork or clay, into the hands of certain children. Encourage the children to give more than one character by which to recognise the substance, or to describe some method of using or testing it in order to make sure, if possible, of the correctness of their inference.

While the children are stating the various characters of the substances, take occasion to direct their attention to the means by which they observe those characters, e.g., by sight, touch, smell, &c. Lead them to speak of these means as their *senses*, and to enumerate the five senses and the organs by which they are exercised.

Point out one or more cases where the children have described two of the substances as having the same character, e.g., sawdust and cork as being light, glass and water as being transparent, &c. Explain that various substances may all be alike in some one respect; and let them select from the specimens all those that would burn, and lay them by themselves. Then point out that we may neglect all other differences, and say that there are on the table two sets or 'classes' of bodies, one containing those that will, and the other those that will not, burn. For some purposes such a division might be very useful, e.g., we might find it necessary to put away in a special place for safety those substances which might possibly be burnt and so destroyed; or we might, in the absence of coal or wood, be looking about for something else of which to make a fire, and then a substance belonging to one class would be useful, while for this purpose those belonging to the other division would be useless.

Lead the children to suggest other bases of classification, and to separate the substances on the table into corresponding sets, e.g., according to colour, smell, whether solid or liquid, whether or not readily penetrated by a nail or a knife, &c.

The children might be exercised in writing down the names of several substances belonging to a given class, about which they have learnt in previous courses of lessons—e.g., black substances, sweet substances, metals, foods, &c.; or in naming two or three substances which might be classed with a given one (butter, chalk, ice, &c.), stating the common property which justifies the association.

LESSON II.

ICE AND WATER.

OBJECTS REQUIRED—*Block of ice (on plate); water (in tumbler); plate; marble (or small stone).*

ANALYSIS OF LESSON.

Characters by which ice is recognised.

Ex.—*Touch it; hold piece in hand, and note melting.*

Relations between ice and water—freezing, melting, &c.

Differences between ice and water.

Ex.—*Press on ice with finger; lay stone on it.*
Lay ice on table; hold piece in hand.
Put finger or rod into water; then stone or marble.
Pour water on plate or table; note spreading, change of shape, &c.

Cause of differences—particles of ice held firmly together—*cohesion*—particles of water loose.

Ex.—*Try to pull one part of ice from other.*
Take drop of water on finger.

Ice is *solid*, water *liquid*—other solids and liquids.

Same substance solid or liquid, according to circumstances.

Natural forms of water as solid (hail, snow, icebergs, &c.), and liquid (rain, rivers, seas, &c.)

NOTES.

Subject of Lesson.—It is intended by this lesson to call attention to the differences between ice and water, to suggest the cause of such differences, and thus to prepare the way for a general lesson on the principles which lead us to distinguish bodies as solids and liquids respectively.

Let the children recognise the piece of ice lying on a plate, and describe what has led them to form that opinion. Ask them to suggest some further means of testing whether they are right, e.g., by touching it and finding it very cold, and by the water which drops from it when held in the hand.

Question the children as to what ice really is; under what circumstances water turns into ice, or ice into water; the names given to these changes (freezing, melting), &c.

Ice being, therefore, merely frozen water, lead them to describe how the water changed when it froze, i.e. how they know that the water in the pools or ponds has, on a particular occasion, changed into ice. Lead them to state such facts as the following—illustrating them yourself, when possible, by means of the piece of ice on the table, or asking the child who states the fact to illustrate it, and to show that it is not true also of the water—the ice is firm enough to bear the pressure of the finger or a stone or book (and on ponds sometimes to bear the weight of many people); and pieces or lumps of it may be held up in the hands, or will lie alone on the table, and still keep the same shape.

Then let the children contrast the water in these and other respects with the ice—let them state how they know the water placed in the glass is still water and not ice. Lead them to describe how the water moves away when pressed on by the finger, or when a marble or small stone is laid on it; that it spreads itself out into a sheet when poured on to the table or a plate, so that it is necessary to put it in some vessel with raised sides to keep it all together; also how it has one shape in the glass, another on the plate, and another still when put into a square bottle.

When the great differences between ice and water are fully realised, it might be pointed out that there must be some cause for these differences. Why, for example, does the water move away so easily to let the finger or a stone pass in amongst its parts, while the ice will not do so? Why can a lump of ice be taken and held between the fingers, while water cannot? Lead the children by such questions to suggest that in the blocks of ice all the small pieces of which they are made up must be tightly fastened together, while all the parts of the water are very loose. Having got the suggestion, show that it explains the various facts previously noted of the two substances. Show how difficult it is to pull one part of a piece of ice from the rest, while it is very easy to separate one drop of water from another.

(If the children are fairly intelligent they might be taught to speak of this power which holds the small parts (or particles) of ice so firmly together, as *cohesion.*)

Lead the children by questions to speak of the ice as a *solid*, and of the water as a *liquid*; to give one or two examples of other solids and liquids, and to state the differences which lead us to describe the substances by the two different names. (This part may be treated very briefly here, as it will form the main subject of the next lesson.)

The fact that the same substance may be at one time liquid and at another time solid—as in the case of water—should also be pointed out.

The remaining time might be spent in a brief consideration of such of the natural forms of water in the solid and liquid state, as illustrate the differences between the two states, e.g., *hailstones*, *snow* and snowballs, *icebergs*, and *glaciers*, as examples of solid masses; while *rain*, and more especially *rivers*, *lakes*, and *seas*, would serve to show by contrast the different behaviour of masses of liquid.

LESSON III.

SOLIDS AND LIQUIDS.

OBJECTS REQUIRED—*Small block of wood; water (in tumbler); methylated spirit; lump of sugar or soda; treacle or turpentine; clay; lead (pieces for melting); spirit-stove; matches; iron table-spoon; lid of small pill-box (to use as mould); plate; duster. (Some unfamiliar solid and liquid.)*

ANALYSIS OF LESSON.

Differences between ice and water; cause of differences.

General characters of solids.

Ex.—*Select solids from objects on table.*

Test various solids by pressure, holding in fingers, standing alone, &c.

General characters of liquids.

Ex.—*Put rod into liquid; shake liquid in bottle.*

Turn bottle on its side, and note flow of liquid and shape.

Differences between solids and liquids.

Solids differ among themselves in many other respects; so liquids.

Cause of change from water to ice, and *vice versâ.*

General cause of change from solid to liquid.

Ex.—*Melt lead in iron spoon over spirit stove; scrape surface with wood, and note characters of liquid.*

Pour molten lead into shallow mould on plate.

Examples and advantages of 'casting.'

NOTES.

Subject of Lesson.—In the last lesson the differences between a special solid and liquid (ice and water) were noted; in this lesson it is shown that the same characters serve to distinguish two large classes of bodies—known as solids and liquids respectively. The members of each class may, however, differ very much among themselves in other respects. The change of a substance from one of these states to the other is briefly discussed.

Question the children on the differences between ice and water, as observed in the preceding lesson, and as to the cause which was then suggested for the differences. Lead them also to give the names *solid* and *liquid* to describe the different conditions of the one substance.

Then let them state whether any of the substances on the table (e.g., block of wood, glass of water, methylated spirit, lump of sugar or soda, chalk, bottle of treacle or turpentine, piece of clay, &c.) could be spoken of as solids; and ask some children to come to the table and separate such from the rest. Point out that this separation may be made without at all knowing what the substances are. (Some examples of solid and liquid substances from the school collection of objects, not known by name to the children, might be included among the specimens to prove this point.)

Let them describe the characters in which all the solids agree with each other and with the piece of ice previously examined. Test several of the substances to see if they have the characters described—e.g., hold them between the fingers, set them alone on the table, press the finger or a pencil on to them, or rest one on the other.

Then examine the other substances not regarded as solids ;—the water was previously called a liquid, would it be right to call any of the others liquids ? Let the children point out which are liquids and describe how they agree with water. Illustrate the facts as far as possible ; e.g., put the finger or a pencil into some of the liquids; shake them in the bottles (to show how loose their particles are) ; turn the bottle on its side and note the manner in which the liquid moves till it comes to something to support it, and that it always has the same shape as the part of the vessel in which it lies.

Encourage the children then to state in their own words the chief differences observed between the solids on the one hand and the liquids on the other.

Then point out that the solid bodies are not alike in all respects ; that in fact one solid may be very different in many ways from another. Let the children recognise and name the solids and state some differences between them. Do the same with the liquids.

Explain that in the last lesson it was found that the solid ice changed into liquid water, and that often in winter water changes into ice. Let them describe what it is which causes these changes, and how they would try to bring about the changes in any particular substance, e.g., lead or wax. Illustrate this by melting some lead in an iron spoon over the flame of the spirit-lamp ; call attention to the way in which the solid pieces of lead, which at first had a particular shape of their own, run together when melted and take the shape of the spoon. Carefully scrape the surface of the melted lead with a small piece of wood to show both its bright appearance and also that, like other liquids, it is very easily moved. Then pour the melted lead carefully into a mould (e.g., a shallow lid of a pill-box, set on a plate) and let it solidify. While it is cooling, question the children as to the shape which the molten lead takes when poured into the mould, and the shape it will have when solid. Briefly explain in this manner the advantage of 'casting' iron and certain other substances, when pieces of special shape are required. (The cast disc of lead might be kept for use in subsequent lessons.)

LESSON IV.

WATER AND STEAM.

OBJECTS REQUIRED—*Tumbler of water; shallow tin dish; spirit-stove; matches; glass funnel* (*to stand on dish over water, see fig.* 1)*; two clean slates.*

ANALYSIS OF LESSON.

Examples of liquids; general characters.

Change of water to solid; characters of solids.

Melting of ice; cause.

Changes in water when heated; examples of *evaporation.*

Ex.—*Heat water in shallow tin dish over spirit-stove; place funnel inverted over dish.*

Differences between steam and water—indefinite size; independence of particles; great expansion.

Ex.—*Make drawing of water in tumbler and of steam-cloud from funnel.*

Show drop of water hanging from finger, and small sheet on slate.

Water has some cohesion; steam none.

Change on cooling steam—*condenses.*

Ex.—*Condense steam from funnel on cold slate.*

True water *vapour* is invisible.

Ex.—*Point out invisibility of steam in funnel, and gradual disappearance of cloud formed near end of tube.*

Water vapour is present in our breath.

Ex.—*Condense vapour of breath on slate.*

Water vapour from breath, seas, &c., in air; condenses as *mists*, *clouds*, *dew*, and *rain.*

Expansive power of steam; kettle-lid, steam-engine, &c.

NOTES.

Subject of Lesson.—Water, having been compared with ice to illustrate the differences between solids and liquids, is now compared with water-vapour or steam, to introduce the consideration of the differences between liquids and gases generally, The change from one of these states to the other is also briefly considered.

Remind the children that in the last two lessons water has been described as a *liquid*; let them name some other liquids and briefly describe the several characters common to all bodies of that class.

Then remind them also that water is sometimes found to lose these characters and to become hard and fixed in shape, having its parts all held firmly together. Let them name the substance referred to, describe the conditions under which the change occurs, and speak of ice as being *solid*. Ask them to give examples of other solids and to state briefly in what respects all of them agree.

Next let them describe how solid ice may be turned into liquid water; give the name *melting* to the process, and mention one or more instances of solids being melted.

Suggest the idea that as ice when heated undergoes this change of condition, possibly water, when further heated, might also change in some manner. Let the children describe from previous knowledge the changes which occur on heating water; e.g., the formation of steam or vapour, and the gradual disappearance of the liquid. Heat some water in a small shallow tin dish over a small spirit-lamp or spirit-stove until it boils, and set a glass funnel over the water. (Fig. 1.) (The funnel should be large enough if possible to rest on the sides of the dish all round without touching the water.) While the experiment is proceeding lead the children to describe other instances of heating water—in kettles or saucepans, wet clothes hung before the fire, &c.—and give the word *evaporate* to the process, explaining it as being another way of saying 'vapour-making.'

Ask the children to describe any differences observed between the steam which they see issuing from the stem of the funnel, and the water in the dish—e.g., that the steam spreads itself about in all directions, as if the parts were not held together at all, and that it takes up much more space than the water did.

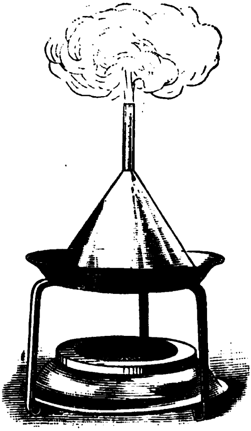


FIG. 1.

Contrast the indefinite expansion of the steam with the definite size of the water in a vessel, bounded by a well-marked horizontal surface. (Simple drawings on the blackboard of a tumbler holding water and the cloud of steam issuing from the funnel would make this point clearer.) Contrast also the manner in which the particles of water, though very loose, still hold together sufficiently to form drops hanging from the finger or other objects [take a drop on the finger], or to lie together in a little sheet on the table, with the apparently complete independence of the particles of the steam. (The children might perhaps be led to express this fact by saying that while water has very little cohesion, steam has none at all.)

Let them again say what has turned the water into steam, and state what might be expected to happen if the steam were made cold. Hold a cold slate in the steam issuing from the funnel, till some large drops of water are condensed on it. Use the term *condense*. Let the children clearly understand that the hot steam was cooled by coming in contact with the cold slate, and that several other means of cooling the steam might be adopted. (The condensation on the sides of the funnel when first placed over the warm water might have been observed.)

Then call their attention to the fact that though steam is seen to be issuing from the tube, none is seen inside the body of the funnel; and further, that the little cloud of steam formed just near the end of the tube passes away into and amongst the air and again becomes invisible. Help them to briefly explain these observations somewhat as follows:—The funnel is full of *water-vapour* which is invisible; this does not condense on the sides of the funnel (as it did on the slate), because they are hot; on coming out of the funnel the vapour cools and forms a cloud (really of small drops of water) which we call steam, and this spreads more and more amongst the air and divides into smaller and smaller parts till it becomes invisible, when we again speak of it as water-vapour.

Tell them that there is water-vapour in our breath, and let them suggest a way of proving the statement, e.g., by breathing against a cold slate or glass, or by reference to the little cloud often seen to be formed from the breath on a cold day.

Tell them that there is always water-vapour passing into the air, not only from our breath, but from warm seas, &c., and lead them to give examples of the condensation of such vapour to form mists, clouds, dew, and rain.

Apply the fact before noted as to the spreading out of the steam to explain the lifting of the kettle lid, the power of steam-engines, and the occasional bursting of boilers when much steam is formed in a small space and cannot otherwise escape.

LESSON V.

LIQUIDS AND GASES.

OBJECTS REQUIRED—*Tumbler of water; spirit-stove; shallow tin dish, or small kettle; matches; blotting-paper; benzoline (in corked bottle); tumbler, with card or paper cover; brown paper for smoke; strong nitric acid; small pieces of copper; clear dry empty bottle; slate; plate; treacle or oil.*

ANALYSIS OF LESSON.

Questions on evaporation of water and condensation of vapour.

Ex.—*Heat water in dish or kettle over spirit-stove.*
Condense vapour from kettle on slate.
Condense vapour in breath on slate.

Wet slate gradually dries; other examples of evaporation.

Other liquids besides water evaporate on exposure.

Ex.—*Wet strip of blotting-paper with benzoline and suspend; note smell.*

Compare benzoline vapour and water vapour,—spreading, &c.

Other instances of substances spreading indefinitely,—coal-gas, &c.

Ex.—*Turn on gas-tap for short time; note smell.*
Put smouldering brown paper in covered tumbler.
Pour nitric acid on copper fragments in empty bottle, and cover.

Smoke, &c., fills out space; liquids may only partly fill vessels.

Ex.—*Compare smoke and nitrogen peroxide with liquid in bottles.*

Characters common to water vapour, benzoline vapour, coal-gas, and nitrogen peroxide.

Gases and *vapours*—general characters.

Gases differ among themselves.

Differences between liquids and gases.

Gases and liquids both flow; 'fluids.'

Ex.—*Pour treacle or glycerine on plate.*
Remove cover from smoke and nitrogen peroxide.

NOTES.

Subject of Lesson.—The differences between water and steam, as observed in the last lesson, are, in the present lesson, shown to be distinguishing characters between two great classes of substances—liquids and gases; the members of each class differing widely among themselves in other respects. As liquids and gases agree in that they flow when not supported, they are often classed together on that account under the one name of 'fluids.'

Commence the lesson with some questions leading the children to state the differences observed in the last lesson between water and water-vapour or steam; and about the means of changing one of these forms into the other. Show them again some water heated to boiling in a little tin dish or kettle, and condense some of the steam on a cold slate. Also breathe on a slate or piece of glass, and let them explain the origin of the drops of water which are formed.

Point out that the wet slate, if left for a time, will gradually become dry, just as wet clothes get dry when hung out in the air; and let them explain this fact by the gradual evaporation of the water. Lead them to give other examples of evaporation, e.g., the drying of the ground after rain, of ink in writing, &c., and to explain that the water vapour thus formed mixes with the air.

Wet a piece of blotting-paper (red by preference) with benzoline (*carefully keeping the open bottle away from any fire or flame*), and suspend the paper by a pin to the edge of the table or to the blackboard. Lead the children to note the gradual drying of the wet paper, to explain it as due to the evaporation of the liquid, and to observe the smell of the vapour as it spreads about the room. Compare the thin benzoline vapour spreading indefinitely in all directions with the water vapour previously mentioned.

Ask the children to give instances of other substances which resemble these vapours in being very thin, and being made up of parts which are not held together, and which are, therefore, able to spread out in all directions. They might instance coal-gas, and smoke—one or both of which should be illustrated, the former by turning on the tap of the gas-pipe for a few seconds, the latter by the smoke from some smouldering thick brown paper which might be laid in a dry tumbler, loosely covered or inverted. (Fig. 2.)

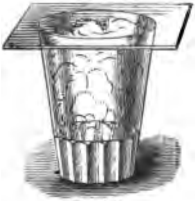


FIG. 2.

Another example of a visible gas might be shown by pouring a few drops of strong nitric acid (being very careful not to get any of the liquid on the hands or clothing) on to some small pieces of copper (wire or strips) in a dry empty bottle or covered tumbler. Let the children describe how the reddish-brown gas (called by the chemist nitrogen-peroxide) which is formed agrees with the smoke, steam, &c. Note, also, how both this gas and the smoke spread out till they completely and evenly fill the vessel in which they are contained; whereas a liquid put into a vessel only fills it up to a certain height, according to the quantity. Illustrate the latter fact by reference to the nitric acid and benzoline in the bottles.

Then explain that the reddish-brown gas just seen, smoke coal-gas, benzoline-vapour, and steam or water vapour [write the various names on the board] all agree with each other in some respects, and let the children state what those are. Say that all of them are spoken of as *gases*; and many other substances, having similar characters, are also known by the same name. Some of the substances (viz., those obtained by the evaporation of liquids, and which are readily changed again into liquids) are also called *vapours*. Point out that these gases are very different from each other in many respects (let the children describe some of these), even though they all agree in the general characters previously stated.

The benzoline and water are both called liquids; let the children name other liquids, and describe the characters in which they all agree. Then let them point out the characters in which the liquids, as a class, differ from the gases.

Lastly, point out that in one respect all gases and liquids agree, viz., that they will spread about if not prevented. Let them see some treacle or glycerine spreading over a plate, and some smoke or nitrogen peroxide spreading out from the vessel when the cover is removed. Explain that this spreading is often called 'flowing,' and that both gases and liquids are, on account of possessing this property, called *fluids*, or bodies that can flow.

LESSON VI.

PRESSURE OF THE AIR.

OBJECTS REQUIRED—*Empty tumbler, with cover; brown paper for smoke; matches; slate; tumbler of water; jug of water; sheet of foolscap; sheet of tissue paper* (*or newspaper*)*; smooth writing-paper to cover tumbler; sucker; glass syringe; glass funnel fitted air-tight through cork in neck of bottle; plate.*

ANALYSIS OF LESSON.

Name several gases and vapours; general characters.

Pressure of gases on sides of enclosing vessel.

Ex.—*Fill covered tumbler with smoke from paper; let some escape.*

Air said to be everywhere around us; why considered a gas?

Proofs of existence of air:—

(1) By effects produced when in motion.

Ex.—*Fan air with slate against face, papers, &c.*
Blow on surface of water.

Effects of winds and draughts.

(2) By its interference with rapid motion.

Ex.—*Move hand or slate slowly through air.*
Hold sheet of paper by one corner and move quickly.
Hold sheet of paper by both hands and move downwards quickly.
Drop sheet of tissue paper spread out horizontally, and also rolled into ball.

(3) By its constant pressure.

Ex.—*Pour water into funnel fitted air-tight into bottle.*
Cover tumbler full of water with paper, and invert.
Lift slate by sucker; stick sucker to board and table.
Raise piston of glass syringe held in water, and lift out syringe containing water.

Air is a gaseous substance spread everywhere, and pressing against all bodies.

NOTES.

Subject of Lesson.—The existence and material nature of the air are made known to us in several ways—by its effects when in motion, its resistance to the motion of bodies through it, and its pressure; these facts, and especially those relating to the pressure of the air, are illustrated in the present lesson.

Ask the children to name several of the substances shown in the last lesson which were said to be gases; and let them state the properties by which all such bodies are distinguished. Lead them especially to describe the manner in which a gas flows or spreads out in all directions, if not prevented by being enclosed in some vessel; and let them infer that, in consequence of this tendency to expand, the gas will press against all sides of the vessel in which it is contained. Illustrate this flow in all directions by putting smouldering brown paper in a covered tumbler; when it has well filled the tumbler, move the cover to one side so as to leave a small opening, and let them observe the escape of the smoke.

Then tell them that we are said to be surrounded on all sides by a substance called air, which spreads into and fills all otherwise empty places, extends over all hills and valleys, lands and seas, and rests in contact with the surfaces of all objects on the surface of the earth. Remind them that in recent lessons they have seen and examined substances, some of which they described as solids, others as liquids, and others again as gases; and let them say, and give their reasons for saying, to which of these classes the air belongs.

The children may next be led to consider the means by which a knowledge of the existence of the atmosphere has been obtained. (Some of these proofs having been described and illustrated in a previous series of lessons, the children themselves should, as far as possible, be led to suggest and explain them.)

(1) The existence and presence of the air are shown by the effects which it produces when in motion. Move loose pieces of paper on the table by fanning them with a slate, move the surface of water by blowing on it, and fan the air against the faces of the children so that they may feel it. Ask the children to describe other instances of effects produced by the movement of the air, e.g., the movement of clouds, dust, leaves, waves, &c., by the wind, and the feeling of a draught near a door or open window—winds and draughts being merely streams of moving air.

(2) The presence of the air is also shown by its resistance to the motion of bodies through it. Point out how easily the hand or other object passes through the air when moving slowly, the particles being so loose and free from each other that they are readily pushed aside. Show, however, by the following experiments that when bodies move quickly, or offer a large surface to the air, there is a difficulty in moving them; (*a*) hold a sheet of paper by one corner and move it through the air, first slowly, then quickly, noting how in the latter case it is pushed or held back by something; (*b*) take hold of a large sheet of paper horizontally by both hands, and move it downwards quickly, noting how it is forced upwards in the middle; (*c*) drop a sheet of thin paper, first when folded up, then when spread out horizontally.

(3) Remind the children of the statement in an

earlier part of the lesson that gases are constantly endeavouring to spread out in all directions, and therefore press against the things which they touch. If the air is a gas it will do this, and the effects of the pressure may be shown in several ways. (*a*) Have a bottle with a well-fitting cork (or better still an india-rubber stopper), and a funnel passing tightly through a hole in the cork. (Fig. 3) Show by putting a knitting-needle or other rod through the funnel that it is quite open; then pour water into the funnel, and let the children understand that the reason why the water does not run into the bottle is because something filling the bottle (the air) presses against it and keeps it out. (*b*) Fill a tumbler *quite* full of water, and cover the mouth of the tumbler with a piece of smooth writing-paper. Let the children say what there is above and below the paper. Hold the paper on with one hand while the tumbler is inverted and held over a plate or basin; then carefully remove the hand from the paper, and the pressure of the air will support both the paper and the water. (Fig. 4.) Lead the children to describe the air under the paper as pressing against it, and supporting both the paper and the water. (*c*) Hold a sucker (made of leather soaked in water till quite soft) by the string in the air, and let the children say what is above and below the sucker. Then place the leather on a smooth surface

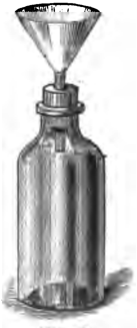


FIG. 3.

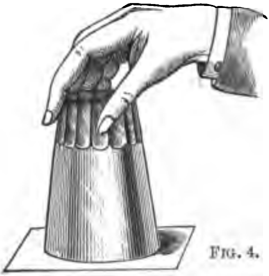


FIG. 4.

(e.g., a block of wood or a slate), press it down to force the air from between the leather and the surface, and lift up the wood or slate by means of the sucker. (Fig. 5.) Explain that something on the top of the sucker presses it firmly against the surface. Use the sucker on the blackboard or table in various positions to show that the air presses in all directions.

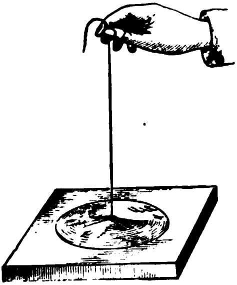


FIG. 5.

(*d*) Place the end of a glass syringe in water and raise the piston. (Fig. 6.) Let the children note how the water is forced in to fill up the space left by the piston and lead them to apply the knowledge acquired in previous experiments to explain that the air resting on the surface of the water in the vessel presses it down and forces it into any space where room is made for it. (It may, perhaps, be necessary to previously wet the cotton wound round the piston of the syringe in order to make it work well.) Lift the syringe out of the vessel by the piston rod, and note how the water is kept in the tube of the syringe, although there is a hole in the bottom. Let the children explain this latter observation.

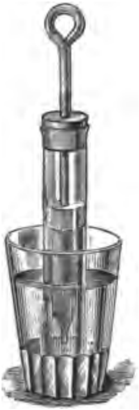


FIG. 6.

Then point out that these experiments all show that there is some substance present about us which presses against the surface of bodies in the same manner as it was inferred the air, if a gas, would do.

LESSON VII.

A POP-GUN.

OBJECTS REQUIRED—*Hollow india-rubber ball, with hole in side; similar ball without hole; common toy pop-gun* (*Fig.* 7).

ANALYSIS OF LESSON.

Briefly revise facts about pressure of air.

Enclosed air resists compression.

Ex.—*Press together sides of india-rubber ball with opening.*

Press together sides of ball closed by finger.

Prove escape of air in first case.

Compressed air exerts increased pressure on enclosing vessel, and assumes original size when pressure removed.

Ex.—*Note strain on sides of closed ball when pressed.*

Sum up result of observations on balls.

Parts of pop-gun—tube, rod, inner cork or plug, loose cork.

Action of air enclosed between the corks; compression, resistance, and pressure.

Ex.—*Shoot gun; note corks do not touch.*

Noise due to sudden rush of compressed air.

Explain necessity for each cork fitting tightly.

Ex.—*Try to shoot gun while end cork very loose.*

Explain necessity for tube being strong, straight, and of uniform size.

Effect of crack or hole in side of tube.

(Gases from gunpowder in ordinary gun expel bullet by their expansion.)

NOTES.

Subject of Lesson.—The examination of a simple toy—the common pop-gun—serves to illustrate in a special manner several facts about the pressure of the air, and the way in which the pressure increases as the air is compressed. It will also introduce the idea of elasticity, which property is to be considered more fully in the succeeding lessons.

[The children might be shown the pop-gun, and some of those who recognise it be allowed to show how it is used. Then with a promise to find out how it works, if they can first tell something of their last lesson and explain one or two other facts, the gun may be laid aside for a little time.]

Ask the children to state the main facts about the air which were considered in the last lesson, and to describe some way of demonstrating the pressure of the air.

Show them a hollow india-rubber ball with a hole through its side; lay it on the table and show them how easily the sides of the ball are pressed together. Then close the opening with the finger and show how much more difficult it is under those circumstances to press the sides together. Let the children explain clearly the cause of the difference in the two cases—viz., that in the second case the air shut up in the ball prevented the sides being readily forced together, while in the first case as the sides were pressed together some air from the inside escaped. (Ask the children how the escape of the air could be shown, and let some one take the ball in his hand and prove the statement.)

Using the same ball with the hole closed by the finger, or a similar ball having no opening, press hard on the sides, and draw attention to their firm and tightened appearance as if something were trying to stretch or break through them; let the children explain this as due to the pressure of the enclosed air. Show that the more the air is pressed together (compressed) the more does it in its turn seem to be pressing and trying to escape in all directions. Also call attention to the fact that when the pressure of the fingers is removed the air goes back to its old size and former quiet condition. Assist the children to describe the result of these observations as showing that the air tries to prevent being forced together into a smaller space, that when compressed it presses hard in its attempts to get back to its old size, and does so return as soon as the pressure on it is removed.

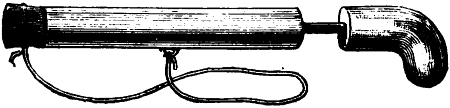


FIG. 7.

Then, saying that they ought now to be able to find out how the pop-gun works, let them examine it (Fig. 7) and see the parts of which it consists—viz., a straight wooden or metal tube, with a cork or plug inside which can be moved along the tube by means of a rod. Putting the other cork tightly in the end, shoot it out quickly; ask the children what pushed it out, and show them that the inner cork did not touch and so press out the other. What, then, did force it out? Lead the children by questions to describe how some air is shut in between the two corks: how, when one cork is pushed towards the other, the air is compressed and presses hard in its attempts to find a way to escape, and how at last it presses hard enough to drive out the loose cork. The air in the gun, like that in the ball, resists being compressed, and so makes it difficult to move the corks together; and as soon as possible after being compressed it goes back to its old size.

Then as to the noise; remind them how the wind (that is, moving air) often makes a noise, and so lead them to explain the report of the gun as due to the sudden rush of compressed air from the tube when the cork flies out.

Next put in the cork at the end loosely and let a child try to shoot it out. Let them explain why it does not act in this case—viz., because the air escapes round the cork and is not compressed. Let them explain why the inner cork must also fit tightly; and why the tube should be straight and of the same size throughout.

Point out that the sides of the tube are strong, and see if they can give a reason for this—viz., that the air when compressed tries to break the sides of the tube and so escape, as well as to force out the cork. Let them state whether the gun would act if the tube were cracked or had a hole in the side, and give a reason for their statement.

(It might be explained that in ordinary guns some gunpowder is put between the closed end of the gun and the bullet, and that when this gunpowder is set on fire it changes into a very large volume of gas, which, like the compressed air, tries to get more room, and in so doing pushes out the bullet.)

LESSON VIII.

INDIA-RUBBER.

OBJECTS REQUIRED—*Hollow india-rubber ball; solid india-rubber ball; large india-rubber band; thick india-rubber cord* (e.g., *a door-spring*)*; specimens of 'elastic'; flat bar of india-rubber; sheets of foolscap paper; book.*

ANALYSIS OF LESSON.

Resistance of enclosed air to compression; restitution.

Ex.—*Press closed india-rubber ball.*

Solid india-rubber ball behaves similarly.

Ex.—*Press solid india-rubber ball with fingers, and on table.*

Other india-rubber articles have same character.

India-rubber bands resist being stretched, and exert pull or pressure.

Ex.—*Child put india-rubber band round book.*
Stretch band in hands; note resistance and tightness.
Note return of band to original size.
Put stretched band over wrist or hand; remove, and note mark showing pressure.

Uses of india-rubber bands, and 'elastic.'

Ex.—*Put band round rolled-up paper.*
Examine specimens of elastic.

India-rubber said to be *elastic* substance; property called 'elasticity.'

Increase in one direction accompanied by decrease in another.

Ex.—*Note thinning of stretched cord or band.*
Note increased resistance and thinning with increased stretching.

India-rubber resists any alteration in shape or size—bending, twisting, compressing, or stretching.

Ex.—*Bend, twist, and compress india-rubber bar or cord; note resistance and restitution.*

(Source of india-rubber.)

NOTES.

Subject of Lesson.—It was observed in the preceding lesson that the air offered a resistance to being compressed, and recovered its original size when the pressure was removed. In the present lesson another substance—india-rubber—which very obviously possesses this same property in a large degree, is fully examined with special reference to this character, which is known as *elasticity.*

Show the children the closed india-rubber ball used in the preceding lesson, and let them state some of the facts then observed of the ball and explain them. Lead them to describe clearly the resistance which the air inside the ball offers to being compressed, and the readiness with which it returns to its original size after compression.

Then show them a solid india-rubber ball, and let some of them try to alter its shape or size by pressing it between the hands, or with the finger and thumb, or against the table. Note how difficult it is to make any noticeable alteration; how the substance seems to resist being changed into a different form, and how readily it returns to its original shape when the pressure is removed. See if the children have observed this character before in connection with india-rubber in any other form (india-rubber bands, &c.) or with any other substance.

Take a large-sized india-rubber band, and let the children describe any use to which they have seen such bands put. Ask a child to put the band round a book (so large that it will be necessary to stretch the band in order to do this), and let the child describe what has to be first done with the band, what stretching means, and whether he feels the band resisting (that is, trying, as it were, not to stretch). Direct attention to the tightened appearance of the band while round the book; let the children say what it appears to be doing to the book—viz. pressing hard against it; and why it is doing so—viz. because it is trying to get back again to its original smaller size. Take the band off the book, and note that it then becomes smaller and loses its tightened appearance. Then put it over a child's wrist, or over two hands held together, so as to stretch the band, and after leaving it for a few seconds take it off to show the mark which indicates the pressure. The india-rubber, therefore, tries to prevent being stretched, and when it is stretched it is all the time pulling and pressing in trying to get back to its old size.

Roll up one or more sheets of paper, or exercise-books, put the band round them and let the children explain its use in such cases. Refer briefly also to the use of india-rubber (woven in with silk or cotton) for gloves, garters, sides of boots, strings for caps and hats, &c., showing specimens if possible.

They may perhaps make use of the word 'elastic' in describing some of the substances used for the purposes just named, and occasion should then be taken to tell the children that because india-rubber, when stretched or pressed, springs back again, it is said to be *elastic*, or an elastic substance; and that all substances which act in a similar manner (e.g., air) are also said to be elastic substances.

Take a piece of thick india-rubber cord (such as is often used for door springs), and let the children describe clearly how to stretch the cord—viz., by pulling at each end in opposite directions. Lead them also to observe that a greater force produces a greater effect, and that the more the india-rubber is stretched, the more it, in its turn, endeavours to pull the hands towards each other. Let the children say whether the stretching has increased the quantity of india-rubber; and lead them by similar questions to observe that it diminishes in thickness in proportion to its increase in length. Show that this is true of the india-rubber band and the other specimens.

Using the thick india-rubber cord (or better still a small bar or flat piece of india-rubber), set the children to twist it, bend it, or compress it; let them observe and describe in each case how there is the same resistance as before to any alteration in shape or size, and the same ready recovery when the applied force is removed. Point out that all these observations show that india-rubber is an elastic substance, or, as it is sometimes expressed, it has the property of *elasticity*.

(If any time remains it might be briefly explained that india-rubber is a kind of gum obtained from the sap of various plants, and that its chief uses are due to the special property just considered.)

LESSON IX.

ELASTIC BODIES.

OBJECTS REQUIRED—*India-rubber ball, band, and cord; cane; (whalebone); string; long wooden rod (pointer); table-knife; tuning-fork; new steel pen-nib; clock-spring; (watch-spring; chair-spring; spring letter-clip; split key-ring); lead (pipe or sheet); ball of soft clay.*

ANALYSIS OF LESSON.

Elasticity of india-rubber; meaning of *elasticity.*

Ex.—*Children demonstrate elasticity of ball, band, and cord.*

Many other bodies are more or less elastic.

(*a*) Cane and whalebone.

Ex.—*Bend cane or whalebone, and release.*

Tie string to ends of cane to make bow; illustrate shooting.

(*b*) Wood—usually breaks if bent far.

Ex.—*Slightly bend long wooden rod.*

(c) Steel—numerous applications on account of its elasticity.

Ex.—*Bend blade of table-knife, and release.*

Press together prongs of tuning-fork, and release.

Children press point of pen-nib on finger, and release.

Bend more, or straighten, piece of clock-spring.

Examine other springs—chair-spring, split-ring, &c.

Some substances have little or no elasticity.

Ex.—*Children test lead by bending.*

Press on soft clay ball, and on india-rubber ball.

Drop clay ball; note no rebound, and permanent flattening.

Drop india-rubber ball, and compare with clay.

List of elastic and practically inelastic substances.

NOTES.

Subject of Lesson.—The property of elasticity having been shown in the preceding lesson to be one of the most striking characters of india-rubber, it has now to be shown that many other bodies possess this same property, but in varying degrees.

Let the children state briefly some of the facts observed about india-rubber in the last lesson, and illustrate their statements by means of an india-rubber band, ball, and cord. Lead them to express clearly what is meant by saying that the india-rubber is elastic, taking care that they mention the resistance which it opposes to any alteration in shape or size, as well as the subsequent recovery after alteration.

Ask them to name any other bodies which they may have observed to act in these respects like india-rubber. If possible give the children specimens of any substances they name in order that they may prove their statements by actual experiment.

Show them a piece of cane or whalebone, and let them observe how it straightens itself after being bent. Let a child bend it, and note that it is necessary to use some force (i.e. to press on it or pull it) to make it bend, and to keep it bent; and that it is all the time pressing in its endeavour to get back to its original shape. Illustrate this latter point by tying a piece of string to the ends of the cane to make the rod into the shape of a small bow. Point out how the string is kept tight and straight, and let the children explain the cause of the tightness. Let them also explain why, when the string is pulled and then released, it flies back to its place, and can thus be used to shoot an arrow. It might also be shown that a wooden rod (e.g., a pointer or a rule) will straighten itself again after being slightly bent; but it should be here explained that some bodies will not bend far without breaking.

The blade of a table knife might next be examined, and shown to be difficult to bend, but able to recover itself readily after the pressure is removed. Point out again that force is needed to bend it, and to keep it bent. Let the children name the substance of which the knife is made, and also, if possible, name other articles made of steel.

Show the children a steel tuning-fork; press the arms of the fork together, and note how they spring apart again when released. Briefly explain that the sound is due to the rapid swinging backwards and forwards of these steel bars after they have been displaced. Take a pen-nib as another object made of steel, and let the children themselves show with it that the substance is elastic,—e.g., by pressing the point of the nib on the thumb-nail to bend it, and then observing how it recovers its shape.

A piece of steel ribbon, or better still a clock spring, should next be examined, and it should be observed how it resists any attempt to alter its shape,—e.g., to straighten it out or bend it more,—and how quickly and perfectly it returns to its original shape after any alteration has been made. The winding up of the spring in a clock or watch should be illustrated; and it should be briefly and simply explained how the spring, as it gradually uncoils itself, causes the wheels of the clock to move round. If possible, other examples of springs should be shown, such as those used for chairs and couches, and those in spring letter-clips, &c. A split key-ring might also be examined, and its elasticity observed. Point out that these various articles illustrate how useful steel is to us on account of this property of elasticity.

Give a piece of lead pipe, or sheet lead, to some of the children, and ask them to examine it and find out whether it is elastic, and, if so, whether it is as elastic as steel. Note how any alteration in shape is not only pretty easily made but is also permanent, or that, at all events, there is very little effort of recovery; and thus infer that some substances have little or no elasticity.

Show the same with a piece of moist clay, noting how an impression made with the finger remains, and comparing it in this respect with an india-rubber ball when pressed upon in like manner. Drop the clay-ball on the table or floor, and note that it is flattened by the blow and remains flattened; then throw the india-rubber ball on the floor, and let the children observe how it bounces (which the clay did not do), and also that any flattening made by the blow instantly disappears.

Lastly, let the children enumerate the various elastic and non-elastic substances examined.

LESSON X.

A SPRING BALANCE.

OBJECTS REQUIRED—*Large india-rubber band; brass or wire* S*-hook; string; books;* 1 *lb.,* 2 *lb.,* 4 *lb. weights, with rings for suspension; foot-rule; spring balance;* (*spiral spring with hooks*)*; jug with handle; cotton thread.*

ANALYSIS OF LESSON.

Force required to stretch india-rubber; also stretched india-rubber exerts force.

Ex.—*Hold up india-rubber band; note size and shape.*
Stretch band by finger; note pressure of finger and of band.

Weight on band exerts a force.

Ex.—*Hang* 1 *lb. weight on band.*

Amount of extension indicates amount of pressure or force used.

Ex.—*Children compare pressure of weight and finger.*
Note extension with 1 *lb. and* 2 *lb. weights on band.*
Repeat experiments, and measure extension with rule.
Hang book from band; measure and estimate weight.

Common spring-balance; contains elastic steel spring.

Ex.—*Stretch spring by pressing on hook.*
Show spring in balance, or other spiral spring.

Same force stretches spring always to same extent; marks on balance.

Ex.—*Hang* 4 *lb. weight on balance, note pointer, remove and repeat.*
Hang 1 *lb.,* 2 *lb.,* 4 *lb. weights on, and note marks.*
Children explain how to find 3 *lb.,* 5 *lb.,* 6 *lb., and* 7 *lb. marks by weights shown.*

Use of balance for weighing.

Ex.—*Weigh jug empty and with water, chair, tongs, &c.*

Use of spring-balance to measure amount of force.

Ex.—*Pull hook with force of* 3 *lbs.,* 6 *lbs., &c., by hand.*
Measure force to move table, board, &c., and to break cotton thread.

'Standard pound' weight; necessity.

Divisions and multiples of pound.

NOTES.

Subject of Lesson.—The common spring balance is another example of the application of elasticity—the property examined in preceding lessons—to a practical purpose. Besides showing this, the lesson will also serve to lead to a consideration of the weight of bodies and methods of weighing, and afterwards to a general lesson on the action of Force.

Hold up a large india-rubber band before the class, and let the children describe its shape and observe its size. Then press with one finger on the lower part of the band so as to stretch it; and lead them to describe the cause of stretching as due to the pressure of the finger. Lead them also to observe the pull of the band on both hands, and to describe it as being due to the power of the stretched india-rubber; a power or force which was, in previous lessons, spoken of as 'elasticity.'

Hang a weight (1 lb.) on the band by means of a small hook (a brass S-hook, or a piece of stout wire bent into that form), and again note the stretching. (Fig. 8.) Point out that the weight must be pulling or pressing on the band in the same manner as the finger in the previous experiment; and let the children state whether the weight presses as much as the finger did, and give a reason for their statement (viz. by com-

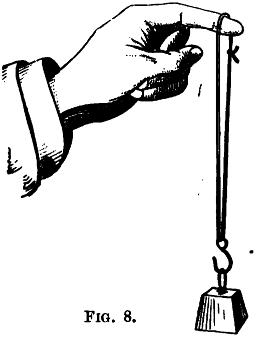


FIG. 8.

paring the amount of extension of the band in the two cases). Hang on a greater weight (e.g., a second 1 lb. weight, or a 2 lb. weight), and note the increased stretching, thus justifying their previous statement. Repeat the experiments, measuring with a rule, first the length (diameter) of the unstretched band, and then when stretched in the various ways described. Take a rather large reading-book, tie a piece of string round it, hang it by the hook from the band, measure the amount of extension, and let the children say what is thus learnt as to the weight of the book, e.g., less than 1 lb., between 1 lb. and 2 lbs., &c.

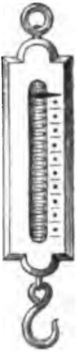


FIG. 9.

Then show the children an ordinary spring balance (fig. 9); let any of them who may have seen such an instrument used, explain what it was used for, and the manner in which it was used. Show them that, like the india rubber band, it contains something which can be stretched by the pressure of the finger or a weight; and that there is also the same force of elasticity acting to bring back the body to its original size. In many spring balances, when the hook is pulled out to some little distance, the coiled steel spring inside the case is drawn out sufficiently to be well seen; this should be shown, if possible. It would also be well to have a spiral steel spring (fig. 10), with a hook attached to each end, to illustrate the action of the balance. (With medium-sized copper or brass wire, a spiral spring may readily be made by tightly coiling the wire several times round a lead pencil or other rod, and then taking out the pencil from within

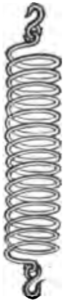


FIG. 10.

the coils.) Similar experiments to those with the india-rubber band above, though perhaps with smaller weights, might be shown with the spring.

Hang a 4 lb. weight on the balance, note the extension, and direct attention to the little pointer which indicates how far that part of the spring has been moved. Remove the weight and replace it several times, to show that the same weight always stretches the spring to the same extent. Hence, if the points to which the pointer is moved by weights of 1 lb., 2 lbs,, 3 lbs., &c., are marked, we can find approximately the weight of any body hung on the hook of the balance. Hang on the 1 lb., 2 lb., and 4 lb. weights successively, and note the marked positions of the pointer. Then let the children describe how to use these same weights to mark or test other points (e.g., by various combinations find points for 3, 5, 6, and 7 lbs.).

Weigh several bodies, e.g. several books tied together by string, fire-tongs, a chair, a jug with and without water, &c., and let some children observe and state the weight in each case. (Very probably half pounds will be indicated on the balance.) Explain that for liquids, and for small bodies that cannot well be hung on the hook, it is necessary to have some vessel or pan, the weight of which must, of course, be allowed for. Let them name some articles that could readily be weighed by the balance without a pan, e.g., meat, clothes, parcels tied with string, &c.

Put the 4 lb. weight again on the balance, and note the pulling force which it exerts. Remove the weight, and ask some child to pull the hook just as hard as the weight had done. Ask another child to pull the hook as hard as a 6 lb. weight would do, and so show them that the spring balance may be employed to measure how much force we use. Draw the mounted blackboard, (or a box or short form) along the floor by hooking the spring balance to the body and pulling it; and let a child observe what force is indicated by the spring balance as being used to move the body. Tie a piece of thin cotton thread to the hook, and pull gently till the thread breaks, noting how far the pointer was moved, and thus finding out what force was used to break the thread. (Speak of the force in each case as a force of 11 lbs., of 8 lbs., &c.)

It may, however, be pointed out that if, in marking the points on a spring balance, we had not correct weights, our measurements would all be wrong. We may not take anything we like and call it a one pound weight. People have agreed how heavy a one pound weight shall be, and Parliament has had a weight made, called the *standard pound* weight; and all other one pound weights are to be just as heavy as that particular one. Then, of course, we can soon find how heavy a 2 lb. or 7 lb. weight should be, or a hundredweight, or a half-pound, or one ounce. (Let the children state the relation between each of these weights and the standard pound.)

LESSON XI.

FORCE.

OBJECTS REQUIRED—*Large india-rubber band; thin cardboard; spring balance; (spiral spring); 1 lb., 2 lb., 4 lb. weights, with rings; S-hook; magnet; compass-needle on pivot (or knitting-needle hung by thread); cotton-thread.*

ANALYSIS OF LESSON.

Force or power is required to stretch spring of balance.

Ex.—*Children pull pointer of balance to named point.*

Some persons can use greater force than others.

Examples of work done by men and animals.

Force exerted by living things may be called '*life-force.*'

Stretched india-rubber or spring observed to exert force.

Ex.—*Put india-rubber band round thin card.*
Attach stretched india-rubber band to two weights on table, and release.

Other elastic bodies can exert same *force of elasticity*; examples.

Recognise magnet, and describe some experiment with it.

Magnet exerts force on certain bodies, which differs from preceding forces;—*force of magnetism.*

Ex.—*Hold pole of magnet near mounted compass-needle; withdraw, and repeat.*

Body hung on spring has power to stretch it.

Ex.—*Hang 4 lb. weight on spring balance.*

Some bodies exert force always on their supports—table, &c.

Ex.—*Set 4 lb. weight on child's hand.*
Hang weight from cotton-thread.

All bodies exert similar pressure; examples of motion so produced;—*force of gravity.*

Other and different forces (heat, &c.) to be learnt about in other lessons.

NOTES.

Subject of Lesson.—The previous lessons on elastic substances will have familiarised the children with the idea of power or force exerted on bodies in various ways, e.g., the force exerted by the person who stretches a piece of india-rubber, and the force which the stretched india-rubber exerts in its resistance to being altered, and in its attempt to return to its original condition. It will be convenient at this stage to introduce a lesson in which this idea of force may be more specially considered, in order to show that there are numerous forces somewhat different from each other in their mode of action, and also to suggest the further idea that all changes in bodies and their motions are due to the action of some cause or force.

Introduce the subject by some questions on the manner of using the spring balance, and lead the children to state that it needs some *force* or power to stretch the spring. Set some children to pull the pointer of the balance to named points (4 lbs., 6 lbs., &c.), and note that they have to use a certain amount of power in order to do this. Note, also, that some persons could stretch the spring more than others (just as some persons could lift a heavier weight than others, or break a thicker piece of stick, &c.), and that we say such people are stronger, or more powerful, than others. Let the children give other examples of work that we are able to do by means of the power or force that we can exert; and also examples of work which other living things (e.g., horses) can do by the exercise of the power or force which they possess. (It might be pointed out that it is because these animals and persons are alive that they can exert this force, and the name '*life force*' might be applied to it, and written on the blackboard.)

It was observed in previous lessons that the stretched spring or india-rubber also exerted a force, by which it resisted being stretched and afterwards returned to its proper size. Illustrate this by placing a stretched india-rubber band round a sheet of paper or thin cardboard, and noting how it bends or crumples up the substance when released; also by attaching an india-rubber band to two weights (say two 1 lb. or a 1 lb. and 2 lb. weights, looping the band over the ring of one weight, and fastening it by a small hook to the other), pulling the weights apart on the table so as to stretch the india-rubber (fig. 11), and then releasing them, noting how they are moved together. This latter experiment might be repeated with a spiral spring, or even with the spring balance. See if the children remember the name given to this power—the power or *force of elasticity*—and write the name on the board under the one previously written. Let the children, if possible, give other examples, from previous lessons, of the action of this force—e.g., a bent bow has power to shoot an arrow, the wound-up spring of a clock to move the wheels, &c.

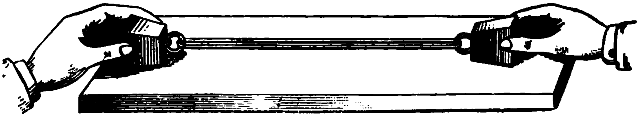


FIG. 11.

Show the children a magnet, and let them, if possible, give its name, and describe briefly one or two experiments which might be performed with it. Bring one pole of the magnet near a horizontal compass-needle mounted on a pivot so as to move freely (fig. 12), or near a knitting-needle hung by its centre from a piece of thread, and note how the suspended bodies move. Remove the magnet, stop the motion of the bodies, and repeat the experiment several times. Point out that when the magnet is near the body 'something' (some power or force) causes the body to move; and in this case it is not your own 'life force,' nor is it 'elasticity' where the substance has first to be stretched or bent to make it work. This force must be called by some other name, and is usually called the *force of magnetism.* Write this name under the others on the board.

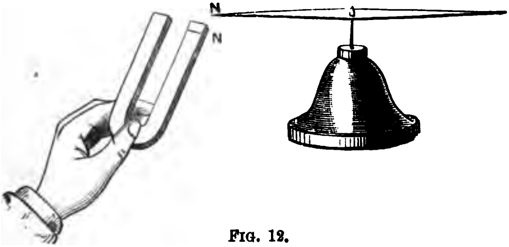


FIG. 12.

Then it was also observed that a weight hung on a spring or india-rubber band could stretch the body (show this), so that there must be some force or power used by the weight. Set a 4 lb. weight on a child's hand, and let him describe how the weight presses on his hand and tries to force it down. Hold up the weight, by a thin piece of cotton thread, and note how the thread is pulled tight (and possibly broken) by the weight, which seems always trying to fall down. Lead the children to understand that the weight when standing on the table is pressing against it, and that all bodies do the same. Also that we ourselves press against the floor or chair on which we rest; and if the floor or chair were to break we should fall, not of our own will, of course, but because some power (or force) makes us do so. Everything about us, then, seems to be trying to get as low down as possible; let the children give examples of this—e.g., water runs down hills, rain, snow, and hail fall, stones fall, and things slide down if the table is inclined. We say it must be because some power or force is acting on all these bodies, and we call this power *the force of gravity.* Write this name under the others.

They thus learn of four forces which make bodies change; and there are others (heat, for example, which melts or turns solid bodies into liquids) which they may learn about at some future time. And there are certain bodies which are useful to us because they have power to do certain kinds of work, e.g., a wound spring can move the works of our clocks. Let the children give examples of other such useful bodies—steam, wind, &c.

LESSON XII.

THE COMMON SCALES AND WEIGHTS.

OBJECTS REQUIRED—*Common pair of scales; weights,* 2 *lbs. down to* ¼ *oz.; spring balance; glass tumbler; jug of water; sand (or other powder), at least* 1 *lb.; scoop, spoon, or broad knife for use with sand; two similar books; half-pint measure; several pieces of paper (old exercise leaves).*

ANALYSIS OF LESSON.

Action of weight on spring balance; indications of balance.

Ex. – *Hang* 2 *lb. weight on spring balance.*

Other instrument used for weighing; method of use.

Ex.—*Child find weight of tumbler or book.*

Examine parts of balance; pans, and strong beam freely suspended.

Position of beam and pointer and amount of swing when (*a*) pans unloaded, (*b*) unequally loaded, and (*c*) equally loaded.

Ex. – *Show balance unloaded, and set it swinging.*
Place one or two sheets of paper in one pan, and note position and manner of swing.
Load both pans equally, and note beam and swing.

Experiments in weighing with balance.

Ex.—*Put paper in each pan, and weigh* 1 *lb. of sand.*
Divide sand equally between pans, and test with ½ *lb. weight.*
Divide ½ *lb. of sand equally between pans, and test with* ¼ *lb. weight.*
Weigh 4 *separate ounces of sand; put together against* ¼ *lb. weight.*
Children select various combinations of weights— 7 *oz.,* 1¾ *lbs., &c.*
With 1 *lb. and* ¼ *lb. weights in pans, balance with sand; state quantity of sand, and test.*
Weigh 8 *oz. water in counterpoised tumbler; pour into half-pint measure.*
(Find weight of half-pint of water.)

Advantages and disadvantages of scales and spring-balance.

NOTES.

Subject of Lesson.—The weight of bodies having been referred to in the two preceding lessons, and one method of determining the weight having been described, it is now proposed to consider the more usual method of weighing bodies, and the common scales and weights employed for this purpose.

Hang a weight on the spring balance and question the children as to the effect produced, the cause of this effect, as described in the last lesson, and the manner in which the instrument indicates that one weight presses more than another, i.e., is heavier.

Then let the children say what instrument is more generally employed for the purpose of weighing bodies. Show them a pair of scales (large enough to carry at least 1 lb. in each pan); let them point out where the body (say a book or glass tumbler) to be weighed must be put, and state what else would be required—viz., 'weights.' Let some child go through the process of weighing the book or tumbler (the teacher meanwhile holding up the scales if necessary) and state the weight so found.

Next proceed to examine the balance, and lead the children to observe that it consists of two pans, hung from a beam or bar of steel or other metal strong enough to bear a considerable weight without bending, and that the beam is so placed in its supports that it can swing freely.

Let the children observe and describe the position of the beam when the pans are unloaded (viz., horizontal) and that when disturbed it swings about equally on each side of its middle position. (Attention should be called to the upright pointer on the beam and its vertical position when the beam is horizontal.) Then a small weight should be placed in one pan, and the effect on the position of the beam, and the amount of swing observed; also the effect of putting an equal weight (using say two actual weights, or two similar books) in each pan. Lead them to explain the effect as due to the equality or inequality of the pressure of the bodies placed in the pans.

Then further illustrate the method of using the balance, and also the relations between the various common weights, by such exercises as the following,—letting certain children take part in the operations and questioning the others as to the facts observed.

(*a*) Weigh out 1 lb. of sand or other substance on a piece of paper laid on the pan (putting a similar piece of paper in the other pan); then take out the weight, divide the sand equally between the two pans, and test each mass by weighing it against a ½ lb. weight.

(*b*) Divide a half-pound of sand similarly into two equal parts to show quarter-pounds, and test as before.

(*c*) Weigh out 4 separate ounces of sand, and put together to show that they are equal to ¼ lb. weight.

Examine the various weights used, and let the children state their relations to each other, and select various combinations required for stated quantities—e.g., 7 oz., 1¾ lbs., &c.

(*d*) Put a 1 lb. weight in one pan and ¼ lb. weight in the other; add sand to the latter to make the pans balance. Let the children state the quantity of sand used, and test their statement by balancing the sand against the proper weights.

(*e*) Weigh out 8 oz. of water in a tumbler, calling attention to the necessity for first counterpoising the vessel. Show by pouring the liquid into a half-pint measure that 8 oz. of water is rather less than half a pint. (If there is time the weight of half a pint of water might be definitely ascertained.)

Lastly compare the advantages and disadvantages of the spring balance and the common scales respectively—e.g., note the simplicity of the spring balance and the advantage of not having to carry loose weights about with it; but note also the disadvantage of only being able to weigh exactly what has previously been marked on the engraved scale.

LESSON XIII.

SAWDUST.

OBJECTS REQUIRED—*Rather coarse sawdust* (*more than* ¼ *lb.*)*; block of wood; plate; lead pencil; small* (4 *or* 6 *oz.*) *wide-mouthed bottle; pair of scales;* ¼ *lb. weight; two or three sheets of paper.*

ANALYSIS OF LESSON.

Children recognise sawdust; nature, source, and name.

Ex.—*Examine heap of sawdust on plate.*

ompare sawdust with block of wood—differences and cause.

Ex.—*Show wood resisting pressure of hand, standing alone, &c.*

Press on sawdust; force finger and pencil into it.

Parts of wood held together; requires force to make sharp nail separate them.

Measuring amount of sawdust by volume—'bottleful,' &c.

Ex.—*Fill bottle loosely with sawdust; pour in heap on paper.*

Fill bottle with sawdust pressed in, and empty out in separate heap.

Compressing sawdust makes it *denser*, and diminishes spaces.

Measurement by volume not exact test of actual quantity; weight is surer test.

Ex. – *Compare weight of heaps formed by the two bottlefuls above.*

Sawdust is 'light,' because spread out and containing so many spaces.

Ex.—*Weigh out* ¼ *lb. of sawdust.*

Compare size of ¼ *lb. sawdust with* ¼ *lb. weight.*

In iron, brass, &c., the substance is more closely packed—'denser.'

Examples of bodies having (*a*) same size and different weight and (*b*) same weight and different size.

Air in spaces of sawdust displaced on compression of mass.

Explain why external air does not compress sawdust.

NOTES.

Subject of Lesson.—In this lesson it is intended to show that the weight is a more certain indication of the actual quantity of substance in a body than is the size. It will also lead to the general consideration of the existence of considerable spaces in certain bodies, which renders them capable of being compressed.

Pour out a heap of rather coarse sawdust on a plate or sheet of paper; let the children if possible recognise the substance, and, after examining it closely, describe what it really is (viz., small pieces of wood), how it has been brought into that form, and the meaning of the name applied to it.

Show them a block of wood, let them understand that it could be broken up into a large number of small pieces of wood similar to the sawdust, and ask them to point out in what respects the block differs from the heap of sawdust and to state the cause of difference. (Lead them, for example, to explain that the block is one firm solid mass which can stand alone, that it is harder, and that it cannot be readily penetrated by a pencil or a nail, because the small pieces of wood of which it may be supposed to consist are all held fast together, while in the sawdust they are loose. And in this connection it might be briefly explained that when a nail is driven into a block of wood it has to force apart these small pieces; and hence we see the necessity for striking the nail with a hammer and also the advantage of its having a sharp point.)

Fill a small wide-mouthed bottle loosely with sawdust; then empty the sawdust out into a separate heap on a piece of paper, and let the children say how they would describe the quantity in the heap (viz., as a bottleful).

Fill the bottle again, and this time press the sawdust down into the bottle; let the children explain why it is possible to do this, and what difference the pressure makes in the relative position of the pieces (viz., forces them closer together, making the spaces between them smaller). Explain that this pressing together of the pieces of the sawdust is spoken of as *compressing* it; and the compressed sawdust is said to be *denser* than it was before (just as we speak of a 'dense' or closely packed crowd). When the bottle is filled with the compressed sawdust, let the children say whether the quantity in the bottle is the same as before, and give a reason for what they say. Empty it out in a heap on paper and compare it with the heap previously formed. Point out, therefore, that the terms 'spoonful,' 'boxful,' 'bottleful,' or even 'pint,' 'half-pint,' &c., when applied to such substances as sawdust, do not let us know exactly how much of the substance we really have.

See if they can suggest another method of ascertaining and describing an amount or quantity, and of accurately comparing one quantity with another—viz., by weighing. Let them say whether they would expect any difference of weight between the bottleful of compressed and of uncompressed sawdust, and get them to explain clearly the cause of the difference—viz., that there is really more substance in the one case than in the other, although it does not take up any larger space. (The two heaps might be placed on the pans of the balance to compare their weights.)

Then weigh out a quarter of a pound of sawdust on the scales; and see if the children note the great difference in size between the iron (or brass) weight and the sawdust. Pour out the sawdust in a heap and set the weight beside it. Let the children try to explain the cause of the difference. They will probably say it is because the sawdust is 'light' compared with the weight; if so, ask them which was the heavier when on the balance, how the sawdust could be made to take up less room, and whether, if the heap were pressed together into a smaller space, it would weigh any more. Lead them in this way to understand that it is because the substance is spread out over such a large space that we speak of it as light; and that in the case of the iron or brass weight all the parts of the substance are very closely packed together—or, as before expressed, it is 'denser.'

Point out that the experiments have shown that two quantities may have the same size and yet be different in weight; or may have the same weight and yet be different in size. Let the children describe the examples referred to, and if possible give other instances (wood and clay balls; 1 lb. of sugar and a 1 lb. weight, &c.).

Ask them what fills the spaces between the pieces of the sawdust, and what becomes of the air when the sawdust is compressed. Also remind them of the previous lesson on the pressure of the air, and see if they can explain why it is that the air outside and around the heap of sawdust does not press it closer together—viz., because it is prevented by the other air which fills the spaces between the pieces.

LESSON XIV.

CORK.

OBJECTS REQUIRED—*Cork (large size and soft); piece of 'virgin cork' (about 12 × 6 inches); sawdust; plate; hammer; glass of water; balance and weights; corked bottle.*

ANALYSIS OF LESSON.

Children recognise ordinary cork, and describe use.

Nature and source of cork; difference from ordinary wood.

Ex.—*Show piece of virgin cork; let children take it in hands and examine.*

Cork is soft and yielding.

Ex.—*Press cork between fingers; strike with hammer; let fall on floor.*

Press cork into neck of bottle.

Sawdust is soft and yielding; explain reason.

Cork also contains many spaces, and may be compressed.

Air spaces in sawdust explained lightness: so cork.

Ex.—*Balance cork on scales against weights.*

Children hold weights and cork of about equal size.

Effects due to lightness of cork; use for lifebelts, &c.

Ex.—*Drop cork on hand and floor.*

Float cork on water, and note very small portion immersed.

Quantity of solid substance in cork therefore small.

Children describe elasticity of closed india-rubber ball.

Elasticity of cork; use in holding cork in bottle.

Ex.—*Press soft cork between fingers, on table, &c., and note recovery of size.*

Show cork holding fast in bottle.

Cork not readily penetrated by liquids.

NOTES.

Subject of Lesson.—The consideration of some of the properties of cork, especially its lightness, compressibility, and elasticity, will serve to illustrate again some of the facts observed in previous lessons, and also to show further the application of those properties to practical purposes.

Let the children recognise an ordinary cork (of large size), and briefly describe its use. Explain to them that cork is really a kind of wood, or rather the bark of a certain tree—a species of oak growing largely in Spain and Portugal. Show them a large piece of cork bark, such as may be obtained from a florist or seedsman under the name of 'virgin cork.' (This bark, which is the first produced by the trees, is of little use for any but decorative purposes.) Let several children take the piece in their hands to examine it; then ask them to describe how it differs from ordinary wood or bark. (They will probably readily state that it is softer and much lighter than ordinary wood; if so, lead them to explain how they have ascertained those facts.)

Illustrate the soft and yielding character of cork by pressing it between the fingers, by striking it with a hammer or knife-handle and noting the dull sound of the blow, and by forcing it into the neck of a bottle. Let the children explain the probable result of similarly forcing a hard piece of ordinary wood into the neck of a bottle. (If the cork is not thoroughly soft at first, it should either be soaked in hot water for a little time, or be rolled between the sole of the boot and the floor with a certain amount of pressure, until it is softened.)

Then take a heap or a handful of sawdust, and let the children again describe how it is produced; show them that it, too, would be described as soft and yielding. Let them explain the reason of the soft and yielding character of the sawdust, viz., because the numerous pieces have spaces between them, and can easily be pressed closer together. See if they are at all ready to apply a similar explanation to the case of the cork,—viz., that it contains many small spaces, and that its parts, though not separate like those of the sawdust, admit of being rather easily moved together or compressed.

Remind them that the existence of numerous spaces was pointed to as explaining another fact observed about sawdust, viz., its comparatively small weight. Lead them to apply this also to the case of the cork. Illustrate its lightness by balancing a large piece of cork against a small piece of brass or lead (e.g., weighing the cork on the balance), and by letting various children hold in their hands pieces of cork and iron of about equal size. Ask the children to describe other ways of illustrating the lightness of cork,—e.g., dropping it on the floor or on the hand and noting the very slight blow which it strikes, also floating it on water. Note how the floating cork (an ordinary cork placed in a glass of water) pushes down into the water to a very small distance only. Explain the use of cork as floats for fishermen's nets and lines, and also for lifebelts, jackets for lifeboat men, &c.

Lead the children again to explain the cause of this lightness, and to the inference that the small spaces or pores are filled with air enclosed in them. The quantity of real solid substance—the woody part—must, therefore, be very small.

Then ask them to describe what was observed in a previous lesson when an india-rubber ball, full of air and closed, was pressed, viz., that it was first compressed, and then afterwards regained its original shape and size. Let them give the name applied to this property, viz., elasticity. Show, by pressing a well-softened piece between the fingers and on the table, that the same fact is, to a large extent, true of cork. Lead the children to understand the advantage of this property in the use of corks for closing bottles,—viz., that the cork, which has been somewhat compressed by forcing it into the smaller neck of the bottle, is trying to come to its old size, and so presses firmly against the sides of the neck, and is thus held fast. Illustrate these facts by means of a corked bottle. It might also be pointed out that another property fitting it admirably for its common use of closing bottles, is that ordinary liquids do not readily soak into the cork.

LESSON XV.

SPONGE.

OBJECTS REQUIRED—*Sponge; plate; water; basin; methylated spirit; slate.*

ANALYSIS OF LESSON.

Children recognise sponge; describe and explain common use.

Ex.—*Soak up water from plate; wet blackboard with sponge; squeeze out water.*

Explain possible compression of sponge; compare with cork and sawdust.

Pores of various sizes; *porous* bodies.

Ex.—*Children point out pores; note some very small ones.*

Pores contain air; comparative lightness of sponge, cork, &c.

Water passes into pores; compression diminishes pores and expels water.

Ex.—*Soak up water from plate; press out little, then more, liquid.*

Sponge heavier when holding water; why?

Ex.—*Let child hold dry sponge, then when full of water.*

Sponge sinks in water; explain; compare with cork.

Ex.—*Put sponge on basin of water.*

Examples of other substances soaking up liquids; what inference?

Sponge soaks up other liquids besides water.

Ex.—*Soak up methylated spirit from slate; moisten hand and board; note smell.*

(Source of sponge.)

NOTES.

Subject of Lesson.—Another porous substance—sponge—is now to be examined; and this will illustrate clearly a further means by which the existence of small spaces in many bodies may be demonstrated, viz., their permeability by liquids.

Show the children a piece of sponge (the larger the better) as the substance to be next examined; let them describe its uses, and, as far as possible, explain them,—e.g., it will soak up and hold a quantity of water, and feels soft when rubbed against the skin, &c. Illustrate its power of soaking up water from a plate, of holding water, and so being able to wet the hand or the blackboard, and of giving up the water again when compressed. It would be well to moisten the sponge just before the lesson, and to squeeze it as dry as possible again, since a perfectly dry (and especially new) sponge does not readily soak up liquids.

Then proceed to examine the sponge so as to enable us to explain, as far as possible, the facts just observed. Let the children, for example (after examining the sponge carefully), explain how it is that the sponge may be squeezed together or compressed. Compare it with the cork and sawdust, previously examined, as containing numerous spaces. Let the children point out the largest holes, lead them to observe that there are others smaller and smaller (some very small ones may be seen by looking through the edges of the sponge towards the light), and say that we might perhaps infer (what is really the case) that there are still smaller spaces, too small for us to see without a microscope. The name *pores* may now be introduced as a name for the spaces which exist in bodies, and bodies containing pores may be spoken of as being *porous*.

Ask the children what substance they suppose is present in these pores, and remind them that, in previous lessons, the supposed existence of so many air-spaces in sawdust and cork was believed to explain their lightness. Let the children note the comparative lightness of dry sponge; and also a certain amount of elasticity after compression.

Lay the sponge in some water on a slate or plate, and note how the water is taken up by the sponge. Lead the children to understand that the liquid has passed into the pores of the sponge, and that if there were no spaces the water could not have penetrated. Then ask them to explain why the water comes out again when the sponge is compressed, viz., because the size of the pores is diminished; and show that the amount of water expelled varies with the amount of compression.

Let a child take the dry sponge in his hand, soak up as much water as possible with it, and then state what difference he observes as he holds it, viz., it is heavier. Let the children explain why it is heavier than before, viz., because water has taken the place of the air in the pores, and water is a heavier substance than air.

The sponge might be placed in a large glass or basin full of water, and the children asked to explain why, if it is a light substance, it does not float like cork—viz., because the water soaks into it, but will not soak into cork. (A piece of new dry sponge will float on water.)

Ask them to give examples of any other substances that will soak up liquids; e.g., blotting-paper, bread, calico, &c.; let them explain what such fact shows about those substances, viz., that they are porous. Say that you will want them to give particulars of many porous bodies in the next lesson.

Another question which might arise is whether sponge will soak up any other liquid besides water (and such liquids as milk, ink, &c., which are mainly composed of water). Put a small quantity of alcohol (methylated spirit) on a slate, and soak it up with a corner of the previously well-pressed sponge. Wet another slate, or a child's hand, with this part of the sponge, and let them observe the characteristic smell of the liquid.

(If there is time a very brief account of the source of sponge — a substance formed by certain simple animals which live in various warm seas—might be given.)

LESSON XVI.

POROUS BODIES.

OBJECTS REQUIRED—*Cork; sponge; thick string (loosely twisted); water; ink; calico (or flannel); plate; blotting-paper; hollow (closed) india-rubber ball; brown paper for smoke; matches; bread; pumice stone; brick.*

ANALYSIS OF LESSON.

Porosity of cork and sponge; how demonstrated?

Ex.—*Children demonstrate porosity by pressure, &c.*

Many other bodies porous; name and prove.

(1) Piece of string—spaces among fibres; lamp-wick.
  Ex.—*Soak up ink with string.*
    Untwist string to show fibres.

(2) Calico or flannel—composed of fibres.
  Ex.—*Look through calico; pull out some fibres.*
    Soak up water with calico; squeeze dry and repeat.
    Pour water through calico bag on to plate as in 'straining.'

(3) Blotting-paper—composed of fibres.
  Ex.—*Soak up water and ink.*
    Show fibres on torn edge.
  Explain sizing of writing-paper.

(4) Air.
  Ex.—*Compress air in india-rubber ball.*
    Note smoke from smouldering paper spreading through air.

(5) Bread—pores made by action of yeast.
  Ex.—*Compress bread; soak up water, &c.*

(6) Pumice stone—froth of lava stream.
  Ex.—*Note numerous spaces; also lightness and floating.*

Other examples—brick, soil, wood, &c.

NOTES.

Subject of Lesson.—Several porous bodies having been separately examined in the preceding lesson, the general subject of porosity as a character of many substances is now considered.

Ask the children to name the substances examined in the last two lessons; show them specimens of cork and sponge and let them describe in what character the two substances were found to resemble each other, and how the presence of pores in each case was ascertained and might be demonstrated.

Then let the children name any other porous bodies they may know, giving in each case a reason for their statement that the substance is porous. Where possible show them a piece of the substance referred to, and let a child test the substance in the manner described to prove the truth of the statement. The following substances should be referred to, and if not among those suggested by the children should be introduced by the teacher and presented for examination, as far as possible in the order set out.

(1) *Piece of string or white woollen yarn.*—Show it soaking up water or ink. Untwist a portion to show it composed of fine threads or fibres twisted together, so that numerous small spaces will exist between these fibres. The children should be led to think of the wick of a candle or lamp in this connection.

(2) *Flannel or calico.*—Look through the fabric to the light to observe the spaces between the threads; pull out some of the fine fibres of which the threads are composed. Soak up some water with the fabric, squeeze it as dry as possible again, then repeat. Pour some water through a piece of calico folded into the form of

a bag, to illustrate the process of straining or filtering liquids to free them from small solid particles.

(3) *Blotting-paper.*—Show it soaking up water and ink. Tear a piece of dry blotting-paper, show the little fibres projecting from the torn edges, and describe the paper as being made up of a vast number of fine fibres crossing each other in all directions and having numerous small spaces between them. It might also be explained that paper intended for writing upon is dipped in size when being made; and the children might be led to explain the reason for this, viz., to fill up the pores so that the ink will not run or spread in the paper.

(4) *Air.*—Compress the air in a closed hollow india-rubber ball. Show also the smoke from smouldering match or piece of paper spreading itself through and amongst the air.

(5) *Bread.*—The holes in a piece of bread (made by gases coming from the yeast) may be seen, the bread may be compressed between the fingers, and it may be made to soak up water, milk, &c.

(6) *Pumice stone.*—The comparative lightness of a piece of pumice stone should be observed by the children, and explained by them as due to the presence of numerous pores in it. It might also be shown that the pumice will float on water for the same reason. The origin of pumice might be briefly explained, viz., that it was once melted stone poured out from a volcano, and being at that time mixed with a large quantity of steam, this steam on escaping made the stone into a frothy mass (as seen in the case of lemonade, or lemon kali in water) and filled it full of small pores or spaces.

Various other substances might be referred to if time allowed, e.g., ordinary deal wood (which is easily penetrated by a nail or by liquids), chalk or lump sugar (which readily soak up liquids), soil in a flower-pot, bricks, &c.

LESSON XVII.

THE SKIN.

OBJECTS REQUIRED—*Slates; sheet of glass; (magnifying glass; cold glass vessel large enough to put over hand); glass of water; salt; spirit-lamp; matches; small piece of glass for evaporation; duster, or small tongs to hold glass.*

ANALYSIS OF LESSON.

Name several porous bodies—large and small pores.
Our skin said to contain pores.
(**Ex.**—*Show with magnifying glass to several children.*)
Use of skin as protection.
Varying thickness of skin—lips and base of fingers.
Redness of lips due to blood seen through very thin (outer) skin; easily bleed; compare with other parts.
Perspiration, or sweat, after exercise.
Perspiration always coming in health: explain constant evaporation.
Water vapour made visible by condensation.
Ex.—*Breathe on cold slate.*
Hold hand on cold glass or slate.
Several children do same.
(*Hold hand inside cold glass vessel.*)
Evaporation of pure water, and water with dissolved matter.
Ex.—*Evaporate drop of water on glass over lamp.*
Dissolve salt in water, then evaporate drop.
Dissolved matters left on skin when perspiration evaporates.
Necessity for cleanliness of whole skin.
Skin as protection from cold; hair, wool, &c., in animals.
Skin tanned to form leather.

NOTES.

Subject of Lesson.—Some of the facts observed in preceding lessons are here applied to explain various phenomena connected with the skin and its functions.

Let the children name several porous bodies and describe some of the facts which result from their porosity, e.g., lightness, permeability, &c. Let them name some of the bodies which have pores large enough to be easily seen, and others in which the pores are too small to be readily seen with the naked eye. Tell them that our skin is said to contain pores, and that these must therefore be very small, as we cannot see them without a magnifying glass. (An ordinary magnifying glass held at a short distance from the tips of the fingers will show the pores as little dark spots following the lines of the well-marked ridges on the surface of the skin.)

Ask the children to describe some use of the skin, viz., as a protective covering; and remind them of the pain felt on touching a part of the body from which the skin has been removed by a wound. Let them also point out places where the skin is comparatively thick and hard (e.g., the 'hoofs' at the base of the fingers) and others where the skin appears to be very thin and tender (e.g., the lips). Note the difference between the colour of the skin in these parts, and remind them how it is possible to scratch, or even slightly cut, the skin in some places without its bleeding, whilst the least scratch or crack on the lips sets the blood running. It would therefore appear from this observation that the red colour of the lips is due to the fact that the blood is much nearer to the surface of the skin there than in most other parts.

Then let the children say what is sometimes seen on the skin after exercise, apparently having come through the skin. Tell them that this 'perspiration' or 'sweat' is known to be always passing slowly through the pores of the skin in healthy persons; and lead them gradually to explain how it is that the perspiration usually disappears without our seeing it. Compare the perspiration to water; and lead them to describe, as learnt in a previous lesson, how water evaporates when heated, and passes away into the air in the form of vapour. Remind them also that our bodies are warm, and let them infer that, under ordinary circumstances, the liquid coming through the pores on to the surface of the skin, evaporates as fast as it comes, and therefore disappears without becoming visible. When we exercise a much larger quantity of perspiration is formed, and therefore cannot all evaporate so quickly, hence it accumulates on the skin and becomes visible.

Let them, however, describe how invisible water vapour (in the breath for example) may be condensed to a liquid and so made visible. Illustrate this by breathing on to a cold slate. Then lay the hand on another cold slate or sheet of glass for a few seconds and note the wet marks made by the fingers. Let several children do the same on other slates. (If a large *cold* glass could be obtained, and held upside down with the hand inside it for a minute or so, the condensed moisture on the sides would be very plainly seen.)

Then question the children as to what, if anything, would remain behind—first, on the evaporation of pure water, and secondly, on the evaporation of water containing a little dissolved salt or sugar. (This might be illustrated, if necessary, on a piece of tin or glass held over the lamp by a duster or pair of small tongs.) Tell them that the perspiration is not pure water, but is composed of water mixed with small quantities of solid substances (salt, &c.); these are therefore left behind on the skin and mix with dust from the air. Thus show the necessity for frequent washing; since, if the skin is to continue doing its work properly, it must be kept very clean. (See that they understand clearly that the perspiration comes through the skin in all parts of the body, and not merely on the hands and face. This may be proved by reference to the general perspiration over the body after active exertion.)

The use of the skin as a protection from cold, and the various appendages (wool, hair, feathers, &c.) found in different classes of animals, which better fit it for this purpose, might be mentioned. The conversion of skin into leather, and the applications of that substance, might also be touched upon if time allowed.

LESSON XVIII.

A CANDLE.

OBJECTS REQUIRED— *Wax-candle (in candlestick); matches; spirit-lamp with wick; chalk; ink (on slate); blotting-paper; dry glass tumbler.*

ANALYSIS OF LESSON.

Parts of candle—wax and wick.
Substitutes for candle; advantages and disadvantages.
Comparison of candle with lamp.
Wick composed of fibres, and is porous.
Ex.—*Untwist a piece of the wick.*
Liquids (and gases), but not solids, pass into pores of bodies.
Melting of wax and rise in wick.
Ex.—*Light candle and note melted wax.*
Soak up melted wax with blotting-paper.
Differences between solid and liquid wax;—'guttering' of candle.
Ex.—*Incline candle, and let drop of melted wax fall on paper.*
Melted wax in cup-shaped hollow; explain.
Shape of candle.
Methods of shaping solids—moulding, cutting, casting; examples.
Manufacture of candles;—'dips' and 'moulds.'
Connected account of phenomena of burning.
Effect of heating liquid,—vapour.
Melted wax changes to vapour and burns in flame.
(Wax on burning converted into invisible gases,—water vapour, &c.
Ex.—*Condense vapour from flame on cold tumbler.*)

NOTES.

Subject of Lesson.—The examination of a candle and the phenomena to be observed while it is burning will also bring up again for revision several facts and principles learned in previous lessons, e.g., the melting of solids, differences between solids and liquids, the rise of liquids in pores, &c.

Let the children point out the two different parts of the candle (the wick and the wax or tallow), and state of what each is composed. Let them also state the use of candles, and name other things often used for the same purpose (oil lamps, and coal-gas); giving briefly, if possible, a reason for preferring any one of these to the others under various circumstances (e.g., better light, less trouble or dirt, greater convenience in carrying about, &c.).

Compare a candle with a lamp, noting that each has a wick, at the top of which is the flame (when burning), while the wick stands below in the substance to be burnt. Let the children describe the action of the wick and compare it with that of some of the other porous substances examined in a recent lesson. (The rise of ink in a piece of chalk or blotting-paper might again be shown.) The wick of the candle should be examined in order to show the fibres of which it consists, and thus to account for the existence of the numerous small interstitial spaces.

Then by means of questions lead the children to observe that all the substances which have been found (in preceding lessons) to penetrate into the pores of bodies have been liquids (or gases), whereas the substance of the candle is solid. Let the children try to explain how the wax rises in the wick when the candle burns. Light the candle and call attention to the melted wax, letting them explain the cause of the melting. Show also some of the melted wax rising into the pores of a small piece of blotting-paper or loosely twisted string.

Ask them to describe other differences between the solid and liquid wax, e.g., the solid can stand alone (point to the vessel necessary to hold the oil in a lamp), while the liquid readily moves and flows or spreads about. Show a drop falling from the burning candle when inclined, and remind them of the manner in which the candle 'gutters,' or runs down the side, when in a draught. Then lead them to observe and describe the manner in which the melted wax at the top of the candle is prevented from flowing, viz., that it is contained in a cup-shaped hollow; the cup being formed by the slower melting of the wax round the edges, in consequence of its being kept cool by the surrounding air.

Next let them describe the shape of the candle (cylindrical), and also several ways in which solids may be made into definite shapes, e.g., moulding (clay), cutting (wood), or melting and casting (lead, wax, &c.). Let them describe clearly each of these methods and give examples of substances for which each would be suitable. Briefly describe the two methods by which candles are made, viz., by dipping the wick several times in melted tallow for 'dips,' or by casting wax or composite candles in moulds in which the wick has first been fixed.

The children might then be led to give a connected account of what has so far been learnt as to the actions which take place during the burning of the candle, viz., heat from the flame melts some of the wax which rises up the wick to the flame and is there still further heated.

They should next be asked to state the usual result of heating a liquid, viz., the production of vapour. It should be explained that this is the case in the candle, and that the vapour formed by heating the melted wax spreads away from the wick into the body of the flame, and in its turn is there consumed.

(It might also be briefly explained that, in burning, the substance of the candle is not utterly destroyed, or made into nothing, but is merely changed into other substances which happen to be invisible. One of these is water vapour; and the children might be asked to describe how to prove that such water vapour is coming from the candle flame—viz., by condensing some on a cold dry glass tumbler held a short distance above the flame.)

LESSON XIX.

HARD AND SOFT BODIES.

OBJECTS REQUIRED--*Soft clay; block of wood; chalk; pocket-knife; pin; penholder; lead; piece of slate; slate-pencil; steel file (triangular); iron nail; sheet of glass.*

ANALYSIS OF LESSON.

Different ways of shaping solids; cause of difference.

Lists of bodies cut or not cut by knife; former softer than steel.

Softness tested by ease of cutting, scratching, &c.

Ex.--*Children scratch wood, clay, and chalk with point of knife, pin, and finger-nail.*

Press wooden rod against same bodies; note impression.

Selecting softest and hardest of series.

Ex.—*Test clay, slate, and lead with finger-nail and knife.*

Try to scratch one body with another.

Effect of rubbing (*a*) harder, (*b*) softer body against another.

Ex.—*Test knife-blade and slate on each other.*

Compare knife-blade and slate-pencil on slate.

Rub chalk on blackboard.

Steel is variety of iron which may be specially hardened.

Ex.—*Test knife-blade on glass sheet.*

Test edge of file on iron nail.

Scratch glass sheet with corner of file.

Arrange clay, lead, slate, iron, glass, and steel in order of hardness.

Diamond is hardest known substance; glass-cutting.

Hardness of some bodies may be varied—clay, wax, iron.

NOTES.

Subject of Lesson.—Another important character in which solids differ among themselves is that of relative hardness; this lesson is, therefore, devoted to a comparison of a number of solid bodies with reference to their hardness.

Commence by asking the children to describe the various ways, mentioned in the last lesson, of making solids into any desired shape. Ask them also to explain why different solids are treated for this purpose in different ways, e.g., why lead is melted, clay is cut or is moulded by the hands, wood is cut, &c.

Let them give a list of bodies which can be cut with a knife, and another list of bodies which are too hard to be so cut. The substances in the first series are all said to be softer than the steel of which the knife is made. Let the children give any other reasons that occur to them in support of this statement—e.g., let them test such bodies as chalk, wood, and clay, by pushing the knife-point or a pin into them, by scratching them with a pin or with the finger-nail, and by pressing against them with the finger or with a small rod (such as a penholder).

Take several solids (say moist clay, lead, and a broken piece of slate), and let the children first recognise them. Then ask them to say which of those substances they think is the softest; require them to give their reasons, and prove their statements by actual tests. Next let them state which of those same substances they think is the hardest, and, if necessary, proceed to test the substances again in various ways (suggested by themselves as far as possible), such as (1) noting whether they can be marked by the finger-nail, or (2) observing the comparative ease with which they can be scratched by a pin or a knife, or (3) better still, whether one of the substances will scratch the other (the one which is scratched being softer than the one which scratches it).

Then compare a knife-blade with the piece of slate; let them state clearly their reasons for saying that the steel is harder than the slate, and show that the knife will make deep scratches on the slate. Contrast the action of a knife with that of a slate pencil on the slate, the one being harder, the other softer, than the sheet of slate. In this connection the action of writing on the blackboard with soft chalk might be explained.

Next compare the hardness of the knife-blade with that of a sheet of glass; show that the knife will not mark the glass. It might then be explained that some kinds of iron (known by the special name of steel) admit of being made harder than others, and a steel file should be compared with an ordinary iron nail to show that the file will scratch the nail. With a corner of the file it will probably be possible to make a scratch on the glass, showing that the steel of the file is harder than the glass.

The bodies already examined—moist clay, lead, slate, iron, glass, steel—should now be laid in any order on the table, and then arranged by the children in the order of their relative hardness.

It might be mentioned that we know of substances harder even than steel. The diamond, which is the hardest of all known substances, is considerably harder than the hardest steel; and the children would probably be able to tell of its use by glaziers for cutting glass.

In some instances the hardness of substances may readily be varied, and some examples of this might be discussed; e.g., soft clay is made harder by being baked (as in making bricks), sealing-wax is softened when heated, and iron is so far softened when made red hot as to be readily cut, pierced, or beaten into any shape.

LESSON XX.

STEEL.

OBJECTS REQUIRED—*Large sewing-needle; sharpened rod (penholder); wooden block; table-knife; scissors; (saw, chisel, bradawl); lead; pen-nib; steel spring; split-ring; magnet; rusty iron or steel.*

ANALYSIS OF LESSON.

Revise means of testing relative hardness of bodies.

Name hardest substance examined in last lesson; how proved.

Nature of steel.

Articles made of steel; children give reasons for use.

Examination of sewing-needle; point; hardness.

Ex.—*Press sewing-needle into wood-block.*
Press sharp-pointed wooden rod against block.

Examination of knife-blade; back and edge; hardness; sharpening.

Ex.—*Compare thin edge and thick back of knife.*
Press thin edge of piece of lead against wood.

Cutting instruments (cutlery); examples; place of manufacture.

Colour and bright appearance of steel; rusting.

Ex.—*Compare clean key or knife with rusty iron.*

Examination of hammer: iron head, steel face; effects of striking harder and softer bodies.

Ex.—*Strike wood or lead with hammer, and strike hammer-head with lead.*

Elasticity of steel; examples and use (springs, &c.).

Ex.—*Child show elasticity of pen-nib.*
Show elasticity of knife-blade, spring, and split-ring.

Magnets are made of steel.

Ex.—*Attract various steel articles with magnet.*

NOTES.

Subject of Lesson.—This lesson is devoted to a consideration of some of the applications to which steel is put, mainly on account of its notable hardness and elasticity—two properties which have been specially studied in the preceding lessons.

Lead the children to describe how the relative hardness of bodies was tested in the last lesson, to name the hardest of the substances then examined, to explain clearly why it was said to be harder than the others, and to state what would be the effect of rubbing it against those other substances.

Tell them that steel is merely a special variety of iron, which admits of being hardened by special treatment. Let them name as many articles as they can which are made of steel; show them, when possible, the article named, e.g., knife, needle, chisel, saw, scissors, file, magnet, pen-nib, spring, key-ring. Let them state briefly the use of each article; and in every case where they can, give some reason for thinking that steel is a very suitable material for that particular purpose.

Then examine some of the articles more closely. Take first a large sewing-needle, let the children explain why one end is brought to a very sharp point, and ask them to explain why a similar sharp-pointed piece of wood could not be used instead. A piece of wood might be sharpened to a fine point and pressed against another (flat) piece of wood, to show how readily the point is crushed and broken; then the needle might be pressed into the same flat piece of wood to show its superior hardness.

The steel blade of a knife might next be examined, the cutting edge and the thick strong back of the blade pointed out and contrasted, and the reason for the difference explained. The meaning of saying that the edge is 'sharp' should be clearly stated, and the method of sharpening it by rubbing it against some harder surface described. The effect of attempting to cut bodies with a knife made of a softer substance (such as lead) should also be described.

Then point out that not only knives, but nearly all cutting instruments (scissors, chisels, swords, razors, &c.), are made of steel, and for the same reason, viz., its superior hardness. The term *cutlery*, applied to such goods, should be described, and also the place of their manufacture.

The bright shining appearance and grey colour of the steel when quite clean should be observed, and the children be led to describe the change (rusting) which occurs when the steel is exposed for some time to damp air. Show a piece of rusty iron or steel.

A hammer might next be examined, the reason for making the head of iron given (viz., both because it is heavy and hard), and the further reason for often making the face of the hammer of steel. Let the children state and explain the effect of striking a piece of lead or wood (this might be illustrated) with an iron hammer, and the different effect which would be produced by striking a piece of iron with a hammer of wood or lead.

Question the children to see if they remember the advantage of steel for pen-nibs, i.e., on account of its elasticity, and let some of them illustrate the elasticity of the nib. Show also the elasticity of the blade of the knife and of a spring. Let them describe some applications of springs, e.g., for clocks and watches, spring balances, &c. The elasticity of a steel key-ring might also be illustrated.

Magnets are always made of steel, because it is the only ordinary substance which can be made to remain magnetised, and iron (and steel) are the only common substances which are perceptibly attracted by a magnet. Show that the magnet attracts (lifts up) several of the steel articles that have been examined in the course of the lesson.

LESSON XXI.

BRITTLE BODIES.

OBJECTS REQUIRED—*Small sewing-needle; duster; (pliers); block of wood; pen-nib; cord or flat piece of india-rubber; spirit-lamp; matches; stick of sealing-wax; chalk; strip of glass or thin glass tube; slate-pencil; blacklead pencil; hammer; cane; lead; copper-wire; table-knife.*

ANALYSIS OF LESSON.

Revise properties of steel and its applications.

Ex.—*Bend blade of table-knife and note recovery.*

Effect of bending steel too far; knife, needle, nib.

Ex.—*Break thin sewing-needle held by duster or pliers.*
Stick pointed half in wood and break again.
Break pen-nib by pressure on thumb-nail or wood.

India-rubber may be bent and twisted without breaking.

Ex.—*Bend and twist india-rubber block or cord.*

Sealing-wax readily snaps across.

Ex.—*Break sealing-wax by bending.*

Bodies which break in this manner called *brittle.*

Brittleness associated with hardness; wax and steel.

Ex.—*Gradually soften sealing-wax in flame and bend.*
Let wax harden, then try to bend.

Examples of other brittle substances.

Ex.—*Children test chalk and lead-pencil.*
Carefully break strip of glass in duster.

Brittle bodies break readily when dropped, struck, or pressed.

Ex.—*Drop slate-pencil; strike coal with hammer; crush chalk.*

Some kinds of wood brittle, others *tough.*

Ex.—*Break penholder in two; contrast with bent cane.*

Children describe means of ascertaining brittleness or toughness.

Ex.—*Children test lead and copper-wire.*

Soft clay becomes hard and brittle when baked; earthenware.

'Wrought-iron' is tough; chains; contrast with harder steel.

NOTES.

Subject of Lesson.—Another property of many solid bodies—brittleness—is studied in this lesson, especially as it is usually associated with hardness.

Let the children state the properties of steel which have been studied in previous lessons and which render it so useful to us; also let them describe some of the applications of that substance. Illustrate the elasticity of steel by bending the blade of a table-knife and noting its spring or rebound when released. See if the children know what would be the effect of bending the blade too far.

Bend a sewing-needle carefully till it snaps. (This may be done with the fingers, holding the needle, or at least the pointed end, in a duster; or one end of the needle may be held in a pair of pliers.) The pointed part might be broken again by sticking it firmly into a piece of wood and bending it aside. Let some of the children examine the broken pieces to observe how sharply and cleanly it has snapped across. The similar manner in which a steel pen breaks suddenly when bent too far will probably be known to the children and should be referred to.

Contrast the behaviour of the steel with that of a piece of india-rubber, which may be bent double or twisted in any direction without snapping across.

Then take a stick of sealing-wax and show that, like steel and unlike india-rubber, it snaps across when bent beyond a certain limit. (It would be well to ascertain first if the children can state from previous knowledge whether the sealing-wax is more like the steel or the india-rubber in this respect.) Give the term *brittle* as applied to bodies which readily break when we attempt to bend them, or otherwise try by force to alter their form.

Carefully and gradually warm a piece of sealing-wax until it can be bent without breaking. Let the children then describe what they have observed as to the effects of heat upon sealing-wax. Show them that so long as the wax is soft it may be bent without breaking, but that as it becomes hard its brittleness returns. Remind them that steel, which is remarkable for its hardness, is also very brittle; whilst the india-rubber, which was found not to be brittle, is also not hard.

Then let the children give examples of any other brittle substances, showing them, when possible, the substances named. Among the substances mentioned and tested might be the ordinary pieces of writing chalk, the 'blacklead' of a pencil, a slate-pencil, coal, ice, and a piece of glass. The brittleness of glass might be shown by breaking a narrow strip (held in a duster), or by bending a piece of glass tube, previously scratched across with the edge of a file.

It should also be shown by reference to glass, coal, and lump sugar, that the brittleness is the cause of such substances breaking so readily when struck, dropped, or crushed. For example, a piece of glass might be struck with a hammer, and a piece of lump sugar or chalk crushed under the face of the hammer.

The brittleness of ordinary wood (e.g., a match or penholder) should be illustrated, and contrasted with the way in which some varieties (as a piece of cane) may be bent backwards and forwards through a considerable distance without breaking. Bodies of this latter kind may be described as *tough*—toughness being thus the opposite of brittleness.

A piece of lead (sheet or pipe) might be given to a child to test whether it is brittle, and tested both by bending, dropping, and striking it with a hammer. Let the children state what other characters have been previously observed about lead, e.g., its comparative softness, great weight, and want of elasticity. A piece of copper-wire might be examined by another child to ascertain whether it should be described as brittle.

Another instructive example will be found in comparing the plasticity of soft moist clay with the brittleness of the same substance when hardened by baking to form earthenware or brick.

It might also be briefly explained that while the very hard kind of iron known as steel is usually brittle, another and softer kind of iron is very tough and admits of being hammered out without breaking; hence it is generally called 'wrought-iron.'

LESSON XXII.

STRAIGHT LINE AND RULER.

OBJECTS REQUIRED—*Flat ruler; round ruler; chalk; plate; thin string (about 3 feet); thin copper-wire; sheet of foolscap; (large model cube).*

ANALYSIS OF LESSON.

Use of ordinary flat ruler.

Ex.—*Let child rule straight line on board.*

Varieties of lines – straight, broken, curved.

Ex.—*Rule broken line by shifting ruler.*
Rule curved line round edge of plate.
Children draw straight, broken, and curved lines freehand.

Testing straightness of line by ruler.

Ex.—*Test lines drawn by children.*

Ruler assumed to have accurate straight edge; prove by changing its position.

Ex.—*Lay ruler against straight line and slide along.*
Lay plate against curved line and slide along.
Lay plate on opposite sides of line.
(Do same with bent ruler against line ruled with it.)

Advantages and disadvantages of round and flat rulers.

Lines formed by string held loosely, and pulled tight; applications.

Ex.—*Hold thin string by one end; then loosely by both ends.*
Hold string by both ends and pull tight.
Test and rule lines on board with string.
Make copper-wire into straight, curved, and broken lines.

Straight line is shortest distance between two points.

Ex.—*Mark two dots on board, join by various lines, and measure lines with string.*
Show shortest string required between marks when pulled straight.
Draw figure of bow.

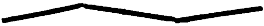
Geometrical figures enclosed by straight lines.

We may neglect thickness of line or size of figure.

NOTES.

Subject of Lesson.—This lesson on the straight line, and the methods of producing and testing it, will serve as the introduction to a short series of lessons, treating in a simple manner of the principles involved in the measurement of lengths, the relation between length, area, and volume, and the determination of the positions of lines and surfaces by the use of the plumb-line and spirit-level.

Show the children an ordinary flat ruler, let one of them use it in ruling a line on the blackboard, and describe the advantage of using such a ruler when drawing a line, viz., as an assistance in making the line straight.

Ask the children to state what other kinds of lines there are besides straight lines, and to draw examples on the blackboard. (They should clearly understand that a straight line may be drawn in any direction—vertical, horizontal, inclined, towards the north, south, &c.—and that lines which are not straight may be either broken lines—i.e., made up of short straight lines in various directions, thus , or may be curved lines. Examples of these should be ruled on the blackboard,—the broken lines being drawn along a ruler which is shifted several times during the course of ruling the line, the curved lines being ruled round the edge of a plate or disc. The children might then draw examples of each kind freehand.)

The method of testing a line with the ruler to see if it is straight should be described, and illustrated by laying the ruler against some of the lines drawn by the children.

Point out that this method proceeds on the assumption that the ruler itself has an accurately straight edge; and show that, to make quite certain, it is best to lay the edge of the ruler against the line on both sides, or to slide it along the line. Show, for example, that the disc used to rule the curved line will fit against the line in the position in which it stood when the line was drawn, but not when moved sideways, or when laid against the other side of the line (fig. 13). (The same facts might also be shown with an imperfect or bent ruler, if one can be found.)

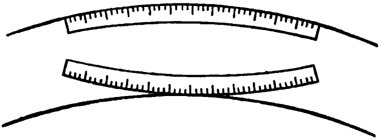


FIG. 13.

Then briefly compare the advantages and disadvantages of round and flat rulers respectively, e.g., the steadiness and accuracy of the one, the easy movement of the other over the paper when several parallel lines have to be drawn, &c.

Taking next a piece of thin string to represent a line, lead the children to observe carefully the differences between the lines formed (1) when the string is held at one end and hangs loosely down, (2) when it is held loosely by the two ends, and (3) when it is pulled tight. With the tightened string test the straightness of some of the lines previously drawn on the board, and also rule a straight line by the help of the string. (The children will perhaps be able to tell of the use of the string to fix a straight line in laying down the kerbstones in the streets, or in digging the foundations of a house, &c.) A piece of copper wire might also be taken and drawn through the fingers, or over the edge of a desk, to form a curved line, pulled tight to make it into a straight line, and bent in several places to represent a broken line.

Mark two dots on the blackboard about 12 or 15 inches apart, and draw a straight line and several curved or broken lines from one to the other. Let the children say which line is the shortest, and test some of them by measurement with the string. Holding the string by the two hands, one against each dot, show that the shortest length of string is required when it is pulled out into a straight line. Show also, on the table or floor, that the shortest distance between any two points is along the straight line joining the points. Make a drawing of a bow on the board, showing the straight string kept tight by the pulling of the elastic wood, and note the greater length of the curved bow.

Let the children name some geometrical figures which are bounded by straight lines, and others which are bounded by curved lines. Note also that the edges of cubes, prisms, &c., are straight lines. It might here be pointed out that in these cases, when speaking of the line, we take no note of any part except the extreme edge; just as in the case of the lines drawn on the board or of the string or wire, we need take no notice of the thickness. We may think of the line as being finer than any thread we have ever seen.

LESSON XXIII.

FOOT-RULE AND TAPE-MEASURE.

OBJECTS REQUIRED—*Two-foot rule; (steel) foot-rule; yard rod; tape-measure; box; large model cylinder; piece of string.*

ANALYSIS OF LESSON.

Varieties of lines; estimation and measurement of relative lengths.

Ex.—*Draw various lines joining two points; estimate longest and shortest.*

Draw figure with 4 unequal sides; estimate order of lengths, and test with string.

Disadvantage of string measurements for description or record.

Use of terms 'yard,' 'foot,' &c., implies agreement as to length.

'*Standard yard*' fixed by Parliament; copies.

Multiples and divisions of yard.

Ex.—*Show yard-rod; child measure length of room.*

Foot-rule or two-foot rule; divisions.

Ex.—*Child measure table with rule.*

Measure distance between points on board.

Rule should be straight.

Tape-measure; divisions agreeing with those of rule.

Tape must be held straight and not stretch.

Relative advantages of tape and rule.

Ex.—*Set children to measure height of table, round chest or cylinder, length of pointer, &c.*

Convenience of winding tape-measure and folding-rule.

Advantage of very long tape-measures for measuring streets, &c.

Instruments measure *lengths* under various names.

Ex.—*Measure length, breadth, and depth of box; height of child; circumference and diameter of disc; diagonal of square; thickness of table, &c.*

NOTES.

Subject of Lesson.—Having in the last lesson considered some of the characters of lines, we have now to examine shortly the common instruments employed in measuring the lengths of such lines.

Mark two points on the board, and join them by several lines (straight, broken, and curved); let the children point out the different kinds of lines and state which is the shortest and which the longest. Then ask them to describe how they would proceed to test the correctness of their statement, and to ascertain by how much one line was longer than another. Make a drawing on the board of a figure with four straight but unequal sides; let the children first estimate the order of the sides according to their relative lengths, and let some child test the statement by measuring the several sides with a piece of string.

Point out that this method would not readily enable us afterwards to describe to others how long the various sides of the figure were, unless we had the piece of string with us and had marked the different lengths. Let the children describe the means by which we are able to describe to another person the length of one or more measured lines, viz., by saying it was so many inches or feet long.

This implies that people understand generally what length we mean by the terms 'yard,' 'inch,' &c., and have agreed to make use of these lengths and names. Explain to them that people (through Parliament) have in fact agreed upon a certain length called a 'yard,' and that this length—called the *standard yard*—has been very accurately marked upon a certain metal bar which is carefully preserved in London. Copies of this bar are made and used in all parts of the country, and yard measures and rules are assumed to be marked with this exact length.

Show the children a yard rod, and let a child use it to measure the length of one side of the room. The advantage of having names for certain multiples of the yard, e.g., a 'mile,' might here be briefly mentioned; and the divisions of the yard into feet, inches, and fractions of inches should be discussed.

Then show them an ordinary foot rule or two-foot rule; briefly examine the divisions marked on it, and let several children use it to measure the length of the table, the distance between two points on the blackboard, &c. Point out while the distance between the points is being measured that, in order to be accurate, the rule must be a straight one, i.e., must extend in a straight line from one of the points to the other.

Then show the children a tape measure, and point out the divisions similar to those on the rule; and mention again the understanding that these divisions have been accurately marked from a correct copy of the standard yard. Repeat with the tape some of the measurements previously made with the rule, pointing out again the necessity for keeping the tape straight; and lead the children to state and explain the necessity for having the tape made of a material that will not appreciably stretch.

Set several children to measure various lengths (leaving them to use either the rule or the tape according to their own choice), such as the height of the table from the floor, the distance round a child's wrist, the length of a pointer, the distance round a child's chest, round a bottle or cylinder, from one corner of the blackboard or table to the opposite corner, &c. Let them explain why in some of these cases the tape measure is much more convenient than the rule.

The children might be led to suggest another advantage of the tape measure, viz., the ease with which it can be rolled up into a small space so as to be conveniently carried. The accompanying disadvantage of being uncertain when measuring whether it is perfectly straight, or whether it may not have shrunk or stretched, might be mentioned. The manner in which some rules are hinged and folded for convenience in carrying should also be described and illustrated. Probably some of the children will have seen used in the streets, or in houses or yards, very long tape measures, and have noticed the manner in which these could be wound up and carried in the pocket. The convenience of using very long measures (rather than ordinary short tapes or rules) in such cases should be explained.

In conclusion, it should be pointed out that in all cases it is really a *length* that we measure with these instruments, whatever name we may call it; thus the teacher, or children, might measure those lengths which we call the *length*, *breadth*, and *depth*, of a box, the *height* of a child or the table, the *circumference* and *diameter* of a disc or cylinder, the *diagonal* of a square, the *thickness* of a piece of wood, &c.

LESSON XXIV.

A SQUARE—AREA.

OBJECTS REQUIRED—*Foot-rule; sheet of foolscap paper; lead pencil; pieces of cardboard or paper*, 1, 2, 4, *and* 12 *inches square, and* 4 *inches* × 2 *inches respectively, having one face of each piece ruled in square inches.*

ANALYSIS OF LESSON.

Examine size of ordinary foolscap sheet.

Ex.—*Child measure length and breadth of sheet.*
Draw similar figure of equal size on board.

Lines of drawing represent *edges* and enclose *surface*.

Ex.—*Shade or colour space enclosed by lines.*

Difference between square and oblong.

Ex.—*Mark length of short on long side of foolscap; fold to form square.*

Characters of square; sides and angles,—*area*.

Ex.—*Draw equal square on board; shade area.*

Difference between square and rhombus; angles and diagonals.

Ex.—*Draw equal rhombus on board and shade area.*

Describe size of various squares; 2-inch square, &c.

Ex.— *Measure side of several squares and name.*

Ratio of areas differs from ratio of sides.

Ex.—*Compare sides and areas of* 2*-inch and* 4*-inch squares.*

Area depends on both length and breadth.

Ex.—*Compare* 4*-inch* × 2*-inch card with* 2*-inch and with* 4*-inch squares.*

Square inch as unit of area; principle of length × breadth.

Ex.—*Show faces of cards divided in square inches.*
Children measure slate, paper, &c., and calculate areas.

Larger units of area and relations; square foot, square yard, &c.

Ex.—*Show square foot divided in inches, and square yard in feet.*
(*Card showing square of* $5\frac{1}{2} = 30\frac{1}{4}$.)

NOTES.

Subject of Lesson.—In this lesson the special characters of the square are first considered, in order to lead to the relation between length and area or surface; and this is followed by a consideration of the principle involved in the measurement of area as applied to simple rectangular figures.

Take a sheet of ordinary foolscap paper and let some child measure its length and breadth. Then draw (or let some child draw) on the blackboard a rectangular figure equal to that of the paper, and lead the children to describe that the lines drawn represent the *edges* of the paper, while the space enclosed by the figure represents the sheet, or rather the *surface* of the sheet, of paper. (This enclosed space should then be shaded by drawing lines across it, or by rubbing powdered chalk over it.)

Then make the paper into a square, letting a child mark on each of the long sides a distance equal to a short side, ruling a line to join the two marked points, and doubling back the piece of paper in excess. Let the children name the figure now formed by the paper, state how the original figure differed from this, and describe the characters of a square. (A similar square should be drawn on the board, and it might again be pointed out that, while the lines drawn represent merely the edges, the term square applies to the surface or *area* enclosed by those lines.)

Then a rhombus, with side equal to that of the square of paper, should be drawn on the board, and the children led to describe clearly how it differs from a square. Lead them to note both the difference in the angles, and also that while both *diagonals* of a square are equal, those of a rhombus are unequal. Again point out that the rhombus encloses a certain area. By this time they should have come to realise the distinction between lines or lengths and surfaces or areas.

Next show the children two or three squares of paper or cardboard, previously prepared, having sides of 1 inch, 2 inches, 4 inches, and 12 inches respectively (using first the plain, unmarked sides). Let them examine the figures to see that they are squares, and then state the size of each piece after measurement, e.g., 1 inch square, 4 inches square, &c.

Compare the 2-inch and 4-inch squares; first note that the sides of one square are twice as long as those of the other, and then lay one square on the other (making one angle of each coincide) to show that a very different relation exists between the areas. This proves, therefore, that surface or area is different from length and must be specially measured.

Then show them a piece of paper or cardboard 4 inches × 2 inches, and note that it has a certain surface or area. Lay the 2-inch square on the oblong, so that a side of each coincides, and let the children explain why the surfaces in this case are unequal. Point out that this shows how it is necessary to observe the lengths of the *two* adjacent sides of the oblong in considering its area. In the same manner compare the oblong and the 4-inch square.

Show the children a square inch, and explain that the term is applied to the surface and not to the lines forming the edges. Explain that the size of one of the other squares might be described by saying how many such square inches would be required to cover it.

NOTES.

Subject of Lesson.—As the square was studied in the last lesson to introduce the idea of surface or area, so now the cube is to be studied in order to lead to the conception of bulk or volume. This is followed by a consideration of the principles involved in the measurement of the volume of simple and regular solid forms.

Let the children state briefly the subject of their last lesson, and describe the characters by which they would recognise a square. Show them a piece of card or paper 3 inches square; let them examine it, and prove that it is a square. Measure it and ask them to explain what is meant by saying that it is 3 inches square. Then ask them how they would in a corresponding manner state the size of an oblong sheet of paper (such as a sheet of foolscap), viz., by giving the lengths of two adjacent sides. Similarly let them measure and state the size of a slate, window-pane, or table top.

Next lead them to describe how we frequently need to consider not merely the edges of such figures, but their whole surface or area. Let them say in what units (square inches, &c.) such areas may be measured and expressed; and let them calculate the number of square inches in the square and in the oblong sheet of paper before examined.

Point out that there is still a dimension of bodies which has been neglected in previous measurements, viz., the thickness; and this may be because either the thickness is inconsiderable (as in an ordinary sheet of paper) or does not concern us for our particular purpose (as in determining the area of a wall before papering, or the amount of floor space for a carpet, &c.) It would be necessary, if we wished to ascertain by measurement how much substance a box would hold, to measure not only its length and breadth, but also its depth or height.

Show them a cube of 3-inch side; let them observe the six equal square faces (compare them all with the piece of paper previously used), the twelve edges of equal length, and the eight similar solid angles. Show them a cube of 1-inch side, and, if possible, a much larger cube (such as used for model drawing), and let them observe the same characters as in the first cube. Explain that a solid having these characters is always called a *cube*. Let a child measure a side of each cube, and explain how that information is sufficient to describe them, e.g., 1-inch cube, or cube of 1-inch side; 3-inch cube, 8-inch cube, &c.

Calculate the number of square inches on one face of the 3-inch cube, then the total number on its whole surface. Explain once more that this measurement refers only to the surface, and would be as true of a hollow cube having its sides composed of the thinnest film of substance as of one solid throughout. If we wish to estimate or express the entire amount of substance contained in the solid mass—i.e. its 'bulk' or *volume*—we cannot measure it in square inches.

Show them a *cubic inch*, and say that the amount of substance in a block might be expressed by saying that it contained so many pieces, each as large as the one shown, which one might be called the 'unit.' Place together eight inch cubes to make a piece (a cube) containing eight cubic inches; then let the children recognise the cubical shape of the mass so constructed, the length of one side, and the number of inch cubes contained. (Point out that *three* observations of length must be made—first, the width of the mass to show how many inch cubes there are in a row; second, the height to show how many such rows are in the front face; and third, the depth or length from back to front, to see how many such series as those seen in the front face would be required to complete the block.)

Then lead the children to consider how many such cubes would be required to build up the 3-inch cube, viz., three rows of three in a row for the series forming one face, and three such series to make up the block. Let a child put together inch cubes to build up a 3-inch cube if there is sufficient; or else place a row of inch cubes along each of three edges, meeting at one corner of the large cube. (The same fact might also be shown by marking in chalk the square inches on each face of the cube.)

From a drawing on the board (or a model if possible) let the children calculate the number of cubic inches in a cubic foot, and of cubic feet in a cubic yard. The advantage of using these larger units when large quantities have to be measured should be explained.

Then show that the same principle of measurement holds for rectangular solids other than cubes. Build up in inch cubes a block measuring 2 × 2 × 3 inches (or 2 × 3 × 4 inches), and show that the total number of units contained would be found by multiplying together the numbers given by three measurements of length as before. Let several children independently measure a block (say 3 × 3 × 4 inches), and calculate the number of cubic inches which it contains.

Other exercises in the measurement of bulk or volume should, if possible, be carried out, e.g., measuring the internal volume of a rectangular box, of one or more rooms, &c.

LESSON XXVI.

INCH, SQUARE INCH, AND CUBIC INCH.

OBJECTS REQUIRED—*Piece of straight wire* 1 *inch long; paper* (*or thin card*) 1 *inch square;* 1-*inch cube of wood; tape measure; foot-rule; cube; rectangular block;* (*sphere, bottle, or pyramid*).

ANALYSIS OF LESSON.

Inch is measure of *length.*

Ex.—*Children estimate length of wire and test with rule.*

Square inch is measure of *area* or surface.

Ex.—*Children state shape and size of paper, and prove.*
Show wire same length as edges of paper.

Different signification of 'inch' and 'square inch.'

Cubic inch is measure of *volume* or bulk.

Ex.—*Children describe shape and size of cube; prove.*
Compare square paper with faces, and wire with edges, of cube.

Difference between 'square inch' and 'cubic inch.'

Children state units in which to measure string, window-pane, box, &c.

Measurement of length of various lines; neglect thickness, &c.

Ex.—*Child draw straight line on board.*
Measure length of line, and of desk, &c.
Measure round wrist, &c.

'Standard yard' and its divisions.

Measurement of areas; two dimensions.

Ex.—*Draw square and oblong on board; shade enclosed area.*

Areas may be enclosed by lines not at right angles, or by curved lines.

Ex.—*Draw rhombus and circle on board; shade area enclosed.*

Measurement of volume; three dimensions.

Ex.—*Make perspective sketch of cube and oblong prism.*
Measure block and calculate volume.

Solids may be bounded by curved surfaces, or surfaces not at right angles.

Ex.—*Show sphere, cylinder, pyramid, &c.*

NOTES.

Subject of Lesson.—This lesson on the linear inch, square inch, and cubic inch will serve to revise the principal facts learnt in the last four lessons, and at the same time to point out in a more connected way the relations between length, area, and volume.

Show the children a straight piece of thin wire one inch long; let them recognise the substance, estimate its length, and test it by a rule. Write down the name *inch* on the board, and opposite to it the word *length.*

Next show them a piece of paper or card one inch square; let them recognise the substance and the shape, and estimate the size. Lay the wire against each edge of the paper in succession to show that all are equal; then let the children state again the size of the paper and explain why it is spoken of as a *square* inch, instead of an inch. Write the name *square inch* on the board, and opposite to it the term *area* (*or surface*).

Then show the children an inch cube of wood. Let them describe its shape and size, and test their statement by actual measurements. Show that the wire previously used exactly coincides with each edge, and the paper or card with each face. Then let the children explain why the special term *cubic* inch is used, and what it expresses more than square inch and inch respectively. Write the name *cubic inch* on the board, and opposite to it the term *volume* (*or bulk*).

Exercise the children in various ways by asking them to say in which of the three units they would state the size of a piece of string, a window-pane, a block of soap, a table-cloth, a box, the diagonal of a square, &c.

Then let a child draw a straight line on the board; ask the children what other kinds of lines might have been drawn, and question them briefly on the characters of a straight line. Let a child measure the length of the line drawn; and point out how thickness, colour, nature of material, &c., were neglected in this operation, as in the case of the wire previously shown. Question them as to the alternative way in which they might express 12 inches, 18 inches, and 36 inches respectively, and ask a child to show a length of one yard on the tape measure. Then lead the children to describe the means by which it is secured that a yard (foot, inch, &c.) always expresses exactly the same length, viz. by the adoption of a certain *standard yard* by Parliament, with which all our ordinary rules are expected to accurately agree.

Set various children to measure lengths, e.g., the length of a desk, the width of a seat, the distance round a child's chest, the diagonal of a sheet of paper, &c. Point out that it is quite possible to measure the lengths of lines that are not straight, as of the circumference of a circle, or a winding road.

Let a child construct a square on the line previously drawn on the blackboard (first making it an exact number of inches long if necessary). Shade the space enclosed, and compare it with the square of paper to show that it now represents an area. Draw another line on the board equal in length to the first, and on it construct an oblong. Lead the children by a comparison of the two figures drawn to describe clearly the necessity for two measurements at right angles to each other in determining the areas of such figures. Let them find the areas of certain regular surfaces and describe how to express large areas in other units (square feet, &c.)

Show them that areas may be enclosed by straight lines which are not at right angles (e.g., draw a rhombus and let them say how it differs from a square; draw also a triangle, pentagon, &c.). Areas may also be enclosed by curved lines (draw a circle). Say that the rules for finding the areas of such figures are not so simple as those for finding the areas of the squares and oblongs, which alone have been previously considered, and they must be left till the children are older.

Then convert the two rectangles drawn on the board into perspective sketches of solid blocks, and let the children describe what measurements would have to be made in each case to determine the volume, pointing out the sides which would need to be measured. Let a child measure and state the number of cubic inches in a block given to him. Let them also explain why in the case of a cube it is only necessary to make one actual measurement, while in the case of an oblong prism one such measurement is not sufficient.

Then show models or drawings of other solids which are not bounded by faces at right angles (e.g., triangular prisms, pyramids, &c.) or solids bounded by curved or irregular surfaces (e.g., a sphere, large stone, bottle, &c.), and say that there are special rules for finding the volumes of such bodies which are too difficult for them to learn at present.

LESSON XXVII.

A PINT MEASURE.

OBJECTS REQUIRED—*Tumbler of water; jug of water; basin; pint and half-pint measures; empty bottle (square); sawdust; oblong wooden block; rule; (hollow cardboard cubes, with sides of* 1 *inch,* 2 *inches, &c.); funnel.*

ANALYSIS OF LESSON.

Solids measured with rule; why not liquids?

Ex.—*Compare water in tumbler and wood-block.*

Capacity of regular vessel might be measured.

Ex.—*Measure with rule, and calculate volume of square bottle.*

Volume of liquids measured by vessels of known volume (in cubic inches); why not also solids?

Ex.—*Show hollow cubes holding* 1, 4, 9 *cubic inches.*

Standard measure of capacity is *gallon* (holding exactly 10 lbs. of water).

Divisions and multiples of gallon.

Ex.—*Show pint and half-pint measures.*

Use of such measures; note liquid adapts itself to vessel.

Ex.—*Measure pint and half-pint of water.*

Children measure capacity of bottle, basin, jug, &c.

What substances measured with these measures?

Certain small solids may be thus measured—peas, &c.

Ex.—*Fill measure with sawdust.*

Spaces exist between the small solids; effect of pressure.

Ex.—*Press down sawdust in measure.*

Means of ascertaining total volume of such spaces.

Gallon, pint, &c. measure volume or capacity, not weight.

NOTES.

Subject of Lesson.—In the last lesson the method of determining the volume of certain regular solids by measurement with a rule was studied. We have now to consider another and more convenient method of determining the volume of liquids and certain small solids by the use of measures of capacity. This will also serve to illustrate again the difference between solids and liquids.

Show the children a tumbler full of water, and question them to see if they know how quantities of water or other liquids are usually expressed, viz., in pints, half-pints, &c. Lead them to describe how the size of a block of wood was ascertained in a previous lesson (show them a prismatic block), and to explain the reason for not treating the water in the same manner. Lead them to speak of a solid having a fixed shape on account of its particles being held firmly in position, and thus being able to stand alone and to have the rule or tape measure readily applied to it.

Let the children understand that, in the case of a liquid which has to be contained in a vessel, if the vessel were of regular shape the space enclosed by it might be ascertained by measuring with the rule, and then we should know the volume of the liquid filling the vessel. But remind them of the statement in a previous lesson, that the simple rule for finding the volume which was then learned applied only to solids of certain regular shapes, with straight sides at right angles to each other, and, therefore, not to such vessels as ordinary tumblers, jugs, &c. Lead the children to see, however, that the volume (in cubic inches) of a given quantity of liquid might always be found by pouring the liquid into a vessel of such a shape as they had learned how to measure by the rule. (The volume of a square bottle might be measured.) Let them explain why this is possible in the case of a liquid, but not in the case of a solid body (viz., because the liquid adapts itself exactly to the shape of the vessel). Thus we might have vessels made to hold exactly 1 cubic inch, 10 cubic inches, 100 cubic inches, &c., and keep such vessels for purposes of measurement. (Small hollow cardboard cubes of different sizes might be shown to illustrate this point.)

Instead of measuring the volume of a liquid in vessels of the kind just described, people have, however, agreed to take as their *standard* a vessel holding exactly 10 lbs. of water; the volume which such a vessel contains being spoken of as a *gallon*. Then, having agreed on our standard, we can easily arrange to measure half-gallons, quarter-gallons (or quarts), pints, &c., and make vessels which will hold exactly these quantities. Show the pint, half-pint, and any other measures, explaining that the makers are supposed to have made them to agree exactly with the standard measures, and that persons in trade are required to make sure that their measures are exact.

Measure a pint (and then a half-pint) of water, noting how the liquid fills out the vessel, and stands, when the vessel is full, level with its edges. Let some children use the measures to determine the capacity of a tumbler, basin, jug, bottle, &c.

Let the children name as many substances as possible which they have seen measured with similar measures, and lead them to speak not merely of liquids but of such bodies as peas, wheat, &c. Point out that most, but not all, of the substances mentioned are liquids; and ask them to explain why the particular solids mentioned are specially adapted to this process.

Question them to see if they remember a fact observed in previous lessons, viz., that these small solids do not absolutely fill the vessel, but leave numerous small spaces; and also that it is often possible, by shaking or pressing the substance, to force the pieces nearer together, and so to diminish the size of such spaces and increase the amount of substance which the measure will hold. The manner of determining the total volume of these spaces, by finding out how much water could be poured into the measure previously filled with the peas, &c., might be described.

Lastly, it might be again pointed out that the pint, quart, &c., are measures of *capacity* or *volume* and not measures of weight; a pint of water, of milk, of peas, and of sawdust have all the same volume, but differ very considerably in weight.

LESSON XXVIII.

HORIZONTAL SURFACE OF LIQUIDS.

OBJECTS REQUIRED - *Pint measure; jug of water; sawdust; tumbler; block of wood; several bottles containing liquids; string; several marbles; flat-sided bottle; slate; plate; treacle (or glycerine); glass rod.*

ANALYSIS OF LESSON.

Liquid takes shape of vessel, and surface stands level with horizontal edges.

Ex.—*Fill pint measure with water.*

Solid particles may stand up above edges of vessel; liquid would run out.

Ex.—*Heap up tumbler with sawdust.*
Pour sawdust in heap on table.

Liquid must have support at sides; solids need not.

Surface of liquids *at rest* parallel to *horizon*;—*horizontal.*

Ex.—*Show liquids in bottles; hold string parallel to surfaces; draw outline on board.*
Show picture with sea horizon.

Horizontal surface of liquid independent of shape of bottom.

Ex.—*Drop marbles in tumbler partly full of water.*
Incline bottles in various directions and note surface of liquid.
Draw horizontal line on board; test by liquid in flat bottle.
Test surface of liquids in inclined bottles by above line.

Liquid always in lowest possible position; action of gravity.

Ex.—*Incline and invert bottle; note liquid at bottom.*
Put liquid on slate not horizontal.
Put marble on inclined slate; support marble on slate with finger.

All particles of liquid must be supported.

Ex.—*Let drops of treacle fall on plate from rod; note spreading.*
Let other drops fall on first, and also into bottle.
Show by drawings each part supported.
Incline full tumbler; note surface of remaining liquid.
Make drawing of inclined tumbler and liquid.

NOTES.

Subject of Lesson.—The horizontal surface of liquids at rest is one of the most important characters of those bodies, and results from the action of gravity on the particles of the liquid, and the necessity for each particle being supported. The characters of horizontal surfaces are briefly considered.

Fill the pint or half-pint measure with water as it stands on the table. Let the children explain again why liquids are so perfectly adapted to this method of measuring volume. Lead them to observe how the liquid of itself takes up a flat surface level with the edges of the measure when the latter is full.

Then fill a tumbler with sawdust, heap it up above the edges of the vessel, and point out how these small solid pieces can stand above the vessel without any support round the sides. Let the children contrast this with what would occur on pouring more liquid into a vessel already full; and lead them to explain that the running over is due to the fact that one portion of a liquid cannot rest on another unless it is supported round the sides. Pour out the sawdust in a heap on the table, and note how it stands heaped up without lateral support; point out the same fact as being still more marked in the case of a block of wood, piece of chalk, or any other solid mass.

Point to the surface of several liquids in different bottles; hold a rod or piece of string parallel to the surfaces of the liquids, and make an outline drawing on the board of a vessel containing liquid. The surface of water in the pools in the streets, in ponds and lakes, and in the sea (when still) has a similar direction.

Show them a picture in which the sea horizon is represented by a straight line; give the name *horizon* as applied to this line which bounds or limits our view, and explain the term *horizontal* as being applied to describe the direction in which the horizon extends, the direction assumed by the surfaces of liquids generally, and the direction of all lines parallel to such surfaces. (Explain by reference to the waves on the sea, and to a liquid shaken in a bottle, that the surface is only certainly horizontal when the liquid is at rest.)

Drop one or more marbles or stones into a tumbler partly full of water, and note that the horizontal surface is quite independent of the irregular form of the bottom of the vessel. Show the same fact by holding in inclined positions vessels containing liquids; and make drawings of such vessels showing the line indicating the surface of the liquid horizontal in every case. A horizontal line might be drawn on the blackboard to agree with the surface of water in a tumbler or a flat-sided bottle, and then it might be shown that however the vessel was inclined the surface still coincided in direction with the drawn line.

Ask the children in which part of a vessel, partly filled with liquid, the liquid will always be found, viz., the lowest part; and hold a bottle containing liquid in various positions to prove this statement. Let a child hold a slate, in a position not horizontal (test it by reference to the surface of a liquid in a vessel), and show that a marble and some water on such a surface always run downwards. Remind them of the fact learnt in a previous lesson about the force of gravity causing all bodies to fall to the lowest position they can reach, and apply this rule to the case of the marble and the water. Show that the marble may be prevented from rolling down the inclined surface by placing the finger, or a book, or other solid body, against it in such a position as to support it. In the same way the loose particles of liquids can only be prevented from falling by properly supporting them.

Dip a glass rod or a spoon into some thick syrup or treacle (or glycerine); then let several drops fall from the rod on to a plate or porcelain slab. Note how they gradually spread themselves out on the plate into a flat sheet, so that no particle on the surface stands higher than the rest—that is, no part stands up without having other particles to support it at the sides. Let other drops fall on to this flat sheet of liquid or into the bottle again, and note how they slowly sink down into the general mass till all have something at their sides to support them.

Show by drawings of vessels containing liquids that each particle has something by its side (either other particles of the liquid or the sides of the vessel) to act as a support. Incline a tumbler full of water and let some run out on to a plate; lead the children to observe the position of the surface of the liquid left in the tumbler. Then make a drawing of the inclined tumbler (fig. 14), and show by a line the surface of the liquid; pointing out that all the liquid which was above the level of the lowest part of the edge ran out of the vessel, and that all liquid below that level was supported and therefore retained.

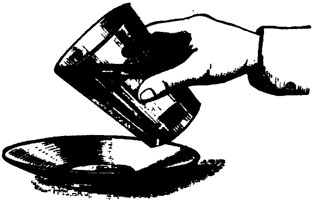


FIG. 14.

LESSON XXIX.

A SPIRIT-LEVEL.

OBJECTS REQUIRED—*Flat-sided bottle half full of water; methylated spirit; glycerine; small round long bottle (phial) or tube, nearly full of water and corked; slate; spirit-level.*

ANALYSIS OF LESSON.

Position of liquid in vessel; nature of surface; air above liquid.

Ex.—*Show flat-sided bottle containing water; incline bottle.*
Incline bottles of other liquids.
Shake bottles of spirit and glycerine; note rise of bubbles.

Air-bubble moves to highest, as liquid to lowest, possible position.

Ex.—*Hold bottle or tube of liquid with bubble in various positions.*

Position of bubble when tube level or horizontal.

Ex.—*Hold bottle level; note position of bubble.*

Spirit-level is tube of liquid with air-bubble.

Ex.—*Show tube of level and bubble.*

Explain term 'level.'

Ex.—*Set spirit-level on table with bubble in middle.*
Children test floor, desk-seats, &c., with level.

Indications of instrument on non-horizontal surfaces.

Ex.—*Child test slope of desks, and book laid on table.*
Test other apparently horizontal lines,—picture-frames, &c.
Child hold slate, on which level stands, horizontal.
Hold level to coincide with surface of liquid in bottle.

Explanation of term *spirit*-level,—spirit or spirits of wine.

Spirit does not freeze; bubble moves very easily;—children explain advantages.

NOTES.

Subject of Lesson.—The application of the property of liquids studied in the last lesson—viz., of moving to the lowest position possible under the circumstances, and standing with a level surface—is of practical importance, and affords us a means of testing the horizontality of surfaces. This is perhaps most conveniently done by means of the 'spirit-level,' the principle and use of which instrument are now to be considered.

Ask the children to describe the position of the surface of a liquid at rest, and to state in which portion of a vessel partly filled with liquid the liquid will be found, what fills the rest of the vessel, and why the liquid is always found below and the air above (viz., because the liquid is heavier or denser than the air). Illustrate these facts by inclining vessels containing various liquids, and by inverting a closed bottle containing water or alcohol. Shake a bottle of water (or, better still, of glycerine), and note the bubbles of air rising through the liquid.

Take a narrow round bottle (phial) having vertical sides (or a long test tube without a flange, or a piece of ordinary wide glass tubing corked at each end) very nearly filled up to the cork with water. Note the small bubble of air in the vessel, and the position which it occupies when the bottle or tube is held upright, inverted, or inclined in various positions. Let the children explain the cause of the bubble moving to these places as the bottle is moved, and describe the position which it would take if the tube were laid on its side (fig. 15) with both ends at the same level. Ask a child to hold the bottle in this position (i.e., horizontally), and observe the position of the bubble.

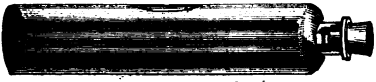


FIG. 15.

Then show them a *spirit-level* (displaying as much of the tube as possible), and point out that it is a small tube or bottle nearly filled with liquid and closed. Call attention to the bubble moving about in the tube as the instrument is moved; set it on the table (so that the bubble is in the middle of the tube), and let a child observe and describe the position of the bubble. Lead them to understand that this position of the bubble shows that the surface on which the instrument stands is *level* (or horizontal), and say that the instrument is on that account called a 'level.' Let several children test other surfaces with the level, e.g., the floor, the seats of the desks, &c.

Ask them whether, if a surface were not horizontal, they could ascertain by means of the level which part was the higher; and let them describe clearly in what manner this would be indicated by the position of the bubble. Let them then test the desk top, a book lying on the table, &c. Ask them to point out other lines or surfaces in the room which appear to be horizontal, and let them test as many as possible, e.g., window-ledges, the upper and lower edges of picture-frames, the blackboard, &c. Place the spirit-level on a slate, and let a child hold the slate as nearly horizontal as possible. Also hold the level to coincide with the surface of a liquid in a flat-sided vessel.

Tell them that the full name of the instrument they have been using is the 'spirit-level,' and that so far only the latter part of the name has been explained. See if any child can suggest a reason for the use of the term 'spirit'; and lead them to understand that it is because the liquid which the tube contains is not water, but what is often called *spirit*, or 'spirits of wine,' or 'methylated spirit'—all of these being common names for varieties of alcohol. The advantages of using such liquid rather than water might be briefly explained as being, in the first place, that it will not freeze under any ordinary circumstances, and secondly, that the bubble of air moves about in the spirit more easily even than in water. Let the children explain the advantage of each of these properties in connection with the instrument.

LESSON XXX.

A PLUMB-LINE.

OBJECTS REQUIRED—*Piece of string; ruler; flat-sided bottle half full of water; spirit-level;* 1 *lb. weight; plumb-line; (plumb-line mounted on board); several inch cubes; tumbler of water.*

ANALYSIS OF LESSON.

Straight lines may be drawn in any direction.

Ex.—*Hold string tight by two hands; note straight line.*

Hold string in various directions.

Rule straight lines in various directions on board.

Term 'straight' indicates kind of line, not position.

Ex.—*Test horizontality of string and line, by liquid in bottle and spirit-level.*

Weighted string pulled straight and in definite direction.

Ex.—*Hang weight from end of string; note swinging and position of rest.*

Substitute other heavy body for weight.

Direction of weighted string at rest called 'upright,' or *vertical.*

Use of plumb-line.

Ex.—*Hang plumb-line from support; hold pointer, string, &c., parallel to line.*

Test walls, door-frames, &c., by plumb-line.

Vertical position necessary for stability of tall bodies; walls, &c.

Ex.—*Set tall pencil and book to stand erect; then incline them.*

Build column of cubes, each slightly projecting.

Advantage of *heavy* body on string.

Ex.—*Hang sheet of paper from string.*

Pull of body on string due to action of gravity.

Relation between vertical and horizontal directions.

Ex.—*Let plumb line hang in tumbler of water.*

Draw vertical and horizontal lines crossing on board.

NOTES.

Subject of Lesson.—The natural relation between the horizontal and vertical directions would suggest that the lesson on the spirit-level, as an instrument used in testing the one, should be followed by a lesson on the plumb-line, as the usual means of testing the other.

Stretch a piece of string tightly by the two hands, and let the children describe what this same experiment was used to illustrate in a previous lesson—viz., the difference between straight and other lines. Show, by holding the string in various positions, that a straight line may be placed in any direction, and also by ruling straight lines in various directions on the blackboard. (Make it quite clear that the term 'straight' simply describes the character or *kind* of line, and tells nothing whatever as to its position.) Lead them to speak of horizontal straight lines, and ask a child to hold the stretched string as nearly horizontal as possible. Let the children state how the horizontality of the string might be tested; and let some of them test the string by means of the spirit-level, and also by the surface of water in a bottle with flat sides.

Then point out that the string may be pulled tight and straight in other ways than by the two hands. Let the children suggest some method. Fasten a weight to one end of a piece of string, hold the string up by the other end, and note how the string is pulled tight to form a straight line. Show that in this case the string takes up a definite direction, and that when displaced it always returns again to the same position. Observe the manner in which it swings backwards and forwards several times on each side of the line in which it will hang when it comes to rest. Substitute some other heavy bodies for the weight first used, to show that the particular material or shape of the heavy body has no effect on the result.

Say that the direction in which a weighted string hangs when at rest is called the *vertical* or 'upright' direction. (The term 'perpendicular,' sometimes used instead of vertical, is incorrect, since a line in *any* direction may be perpendicular to some other line.)

Hang up from the gas-pendant, or some other convenient support, an ordinary *plumb line*, i.e., a string with a rounded 'bob' of lead at the end. Note the straight line and the vertical direction assumed by the string. Then let children hold a pointer, lead-pencil, piece of string, slate, &c., parallel to the plumb-line, and thus learn how it may be used to test whether a body is or is not vertical. Let the children point out bodies in the room which appear to be vertical (e.g., walls, door-frames, supports of blackboard, sides of maps and pictures, &c.), and test some of them by holding the plumb-line near them. (A plumb-line, mounted on a piece of wood (fig. 16) might be conveniently used for this purpose, the straight side of the wood being placed against the part of the body to be tested.)

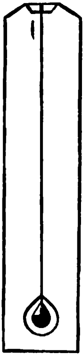


FIG. 16.

Set a new lead-pencil and a large book to stand upright on the table. Let the children note the position, and show, by inclining the objects, that they will not stand unless vertical. Thus show the necessity for placing posts, pillars, towers, &c., vertical, and the advantage of using the plumb-line to enable us to set or build them in their proper position. The necessity for the exact vertical position of walls might be illustrated by building a column of small cubes or books, with each one projecting slightly over the one below it, and then, after it has fallen over, rebuilding the column vertically.

Question the children on the advantage of using lead for the plumb-bob. Let them explain why a heavy body is required; and show them a piece of string swinging with a light sheet of paper hung from the end. Ask them why the heavy body pulls the string; what it seems to be trying to do; and what it would do if it were not prevented by the string. Lead them to speak of the pull of the body on the string, and also its falling back after being lifted aside, as being due to the action of gravity; and let them observe the direction in which the force seems to act, viz., in a vertical direction.

Lastly, show the relation between horizontal and vertical directions—first, by letting the plumb-line hang in water in a vessel, and secondly, by drawing on the blackboard a horizontal line (by means of the surface of a liquid) crossed by a vertical line (traced from the plumb-line). Note that each one is perpendicular to the other.

LESSON XXXI.

A TABLE.

OBJECTS REQUIRED—*Table; rule or tape-measure; straight ruler or* T*-square; marble; spirit-level.*

ANALYSIS OF LESSON.

Use of table.
Height of particular table.
Ex.—*Children estimate height of table and measure.*
Necessity for support *under* bodies; action of gravity.
Special means of supporting fluids (liquids and gases).
Parts of table.
Shape and size of particular table; other varieties.
Ex.—*Children measure length, breadth, and thickness; calculate area.*
Advantage of smooth surface; planing.
Ex.—*Rub hand on surface of table.*
Surface should be flat, not curved or bent; test.
Ex.—*Hold foolscap sheet tight, or against board; then curved in hands.*
Test flatness of table with straight-edge.
Position of legs,—vertical and near edges; equal height.
Top should be horizontal; causes of inclination; tests.
Ex.—*Child test horizontality with smooth marble and spirit-level.*
(Advantage and disadvantage of castors.
Differences in character of various woods used.)

NOTES.

Subject of Lesson.—A brief consideration of the characters of an ordinary table will serve to revise, in a practical form, some of the facts and principles learnt in several of the preceding lessons—the action of gravity, differences between solids and fluids, vertical and horizontal, &c.

Tell the children that much that they have learnt in recent lessons will help them to explain many things in connection with their school and homes, and the common articles they see and use. Say that you wish them in this lesson to observe and explain some facts connected with an ordinary table.

First let them describe the use of a table—viz., to support bodies at such a convenient height that we can get them without stooping or other inconvenience. Let them estimate the height of the table-top above the floor, and then let some one measure it. (Point out to them that they must be careful to hold the tape-measure or rule in a vertical direction in order to get the true height.)

Then let them explain why it is necessary to support bodies, what they do when not supported, why they fall, and in which direction. The fact that bodies tend to fall downwards explains why the support is placed *underneath* them; and the absence of any tendency on the part of a book, for example, lying on the table to move sideways or upwards explains why it is not necessary to support it also in those directions.

Ask the children then whether there are not some substances which tend to spread out sideways; let them mention several, and give the name often applied to this spreading (flowing), and also the general term (fluids) applied to all such bodies. Let them describe the manner in which these substances have to be supported on the table, and distinguish between the conditions necessary for liquids and gases respectively.

Then, coming to the structure of the table, ask them to point out the parts of which it consists—viz., the legs and top. Let them describe the shape of the top of the particular table before them, and also briefly describe any different shapes they have seen in other tables. Next, let them ascertain and describe the size of the top, its length, breadth, area, and thickness.

Rub the hand on the surface of the table, and let the children state what information such proceeding gives as to its character. Let them describe what advantage it has in being smooth; and let some child, if possible, describe briefly how planks of wood are made smooth.

Show them with a sheet of foolscap paper that a smooth surface may be flat (hold the sheet against the blackboard, or carefully hold it tight between the two hands), or bent or curved (hold the paper loosely with two hands, so that it hangs in a curved form between them). Let them say which of the two forms the surface of the table should have, and explain the advantage of its being flat. Let them also, if possible, describe some simple way of testing whether the top of the particular table before them has this character, e.g., by laying the edge of a straight ruler on it in various parts, and observing whether the straight-edge of the ruler fits closely against the surface.

Explain that in making the table, the piece of wood for the top, after being first made flat and smooth, was then fitted to the legs. Let them describe the use of the legs (viz., to support the top at a proper height, and to bear its weight), and the advantage of having them to stand vertical, as is usually the case. Let them also explain why the legs are usually placed very near the edges of the table-top. See if they can suggest any condition as to the size of the legs—viz., that all should be equal in height; and let them state the result if this condition were not satisfied.

The horizontality of the top should next be considered—the necessity for its being horizontal, the causes which might prevent its being horizontal (e.g., unequal length of the legs or inequalities of the floor), and the means of testing the horizontality (let a child test it in various parts with a marble and with a spirit-level). Let them describe how water spilled on a horizontal surface would spread itself, and how it would behave on an inclined surface.

(Any time remaining might be occupied by briefly considering the advantages and disadvantages of having small wheels (castors) at the bottom of the legs, noting how much more easily the round surfaces of the wheels roll than the flat surfaces would slide. A little might also be said about the differences which lead to the employment of different kinds of wood, some being cheap and soft, others harder, others again not only hard but of a beautiful colour and looking very nice when well polished.)

LESSON XXXII.

MOIST CLAY.

OBJECTS REQUIRED—*Soft moist clay on plate (say three balls, each about 2 inches diameter); knife; small (modelling) board; small flat block of wood; round ruler; brick; glass of water; (dry clay powder).*

ANALYSIS OF LESSON.

Properties of solids previously studied; examples of elastic, porous, and brittle bodies.

Test substance (clay) for these properties: first describing method.

Ex.—*Child test for hardness by pressure of finger, and by nail and knife.*

Make clay into ball; drop, and note flattening but not fracture.

Recognise substance; state source.

Change on exposure to air; use.

Clay is solid body.

Ex.—*Show ball of clay lying alone on plate.*

Readily yields to pressure.

Ex.—*Press clay with hand or wood on board.*

Other means of flattening it into sheet,—hammering and rolling.

Ex.—*Strike clay with hand or wood-block.*

Roll out clay into sheet with ruler; note cracking at edges.

Other substances admitting of similar treatment,—putty, dough.

Other substances seen as sheets.

Clay may be *moulded* by fingers into particular shapes; use.

Ex.—*Mould clay into cube or prism, and into hollow cup.*

Clay so moulded may be fixed by baking; then is brittle.

Unbaked clay is impervious to water; ponds, layers in rocks, &c.

Ex.— *Pour water into clay cup.*

Baked clay is porous; glazing of earthenware.

Ex.—*Pour drops of water on brick.*

NOTES.

Subject of Lesson.—Another property of solids to which it is intended to direct attention is the extent to which they yield to pressure and admit of being moulded into shape, and especially of being formed into thin sheets. This property is very well marked in some metals, and will be considered in the next lesson in connection with gold. The present lesson on the plasticity and other properties of moist clay will, however, best serve to introduce the consideration of this subject.

Commence the lesson with some questions on the properties of solid bodies which have been studied in the preceding lessons, e.g., let the children name some special characters of steel (hardness and elasticity), cork, sealing-wax, &c.; let them explain clearly what they mean by each term (elastic, porous, brittle, &c.), and give good examples of other bodies possessing similar properties.

Say that you wish to ascertain whether the particular substance on the table (clay,—but do not mention its name) possesses certain of these characters. Ask a child to ascertain whether the substance is hard or soft. Let him first state how he proposes to test it, and then try the various experiments, e.g., cutting it with a knife, scratching it with the finger-nail, and pressing the finger or a pencil into the mass.

Let other children describe how they would test it to ascertain whether it were elastic; and lead them to describe that they would note whether it recovered its shape after being flattened by pressure or by falling. Make a small piece into the shape of a ball, drop it on the floor, note the permanent flattening, and let them state what it proves. Let them also state what is proved by the fact that the substance changes in shape rather than break into fragments when struck, viz., that it is not brittle.

Ask them whether they can now tell what substance it is which has been used for these experiments; and let them describe the source of the substance, how it changes when left for a time exposed to the air, and how it may again be restored to its present condition. Let them also name various articles manufactured from clay.

Take a rounded ball of clay, lay it on a board or on a porcelain slab on the table, and let the children say what characters prove it to be a solid body. Then press on it with the hand or a block of wood, to flatten it into a disc. Let the children describe other ways of flattening it out so as to make it into a much thinner sheet, e.g., by striking it with the hand or block, or by rolling it with a round ruler. Illustrate both of these methods, and roll out the clay until it begins to crack round the edges. (A little dry clay powder sprinkled on the board or slab will prevent the moist clay from sticking to it. It may, however, be so carefully prepared by mixing together powdered modelling clay and water as to be quite plastic, and yet not to adhere at all to the fingers.) Repeat the experiments if necessary with a second mass of clay; and thus show that the substance when moist admits of being rolled or pressed into a sheet without breaking, but that beyond a certain limit of thinness the sheet begins to crack round the edges.

Let the children name other substances which could be treated in a similar manner, e.g., putty and dough. Point out that each of these, like clay, consists of a powder (i.e., a number of fine particles) mixed with a liquid,—dough being composed of flour and water, and putty of whiting and boiled linseed oil. (Show them, if possible, some dry clay powder.) Let them also name other substances which they have seen in the form of thin sheets, e.g., glass, iron, paper, leather, &c.; all being very different substances in many respects from the soft yielding bodies previously mentioned.

Make a piece of clay into the form of a cube or prism by striking its sides against the table, and model another into the form of a hollow vessel by means of the fingers. Point out that, as one result of being able so readily to *mould* or work clay into any desired shape, it has long been used for the manufacture of many articles; and let the children name some of these, e.g., jugs, jars, plates, bricks, pipes, &c. Describe briefly the subsequent hardening of these articles by drying them in the sun (e.g., sun-dried bricks), or by heating them strongly in a kiln; and see if the children remember from a previous lesson the fact that the articles when so treated become brittle as well as hard.

Pour some water into the moulded vessel to show that the clay does not readily allow water to pass through it. Remind them that ordinary soil was, in a former lesson, said to be porous and to allow water to soak into and through it; and tell them that often, when it is required to retain water in a hollow dug in certain kinds of rock, the sides of the hollow have to be plastered over with clay. It may be possible to refer to the manner in which water stands about in an old brickfield in the neighbourhood, especially after rain. Explain also that even a thin bed of clay in the ground prevents the water which soaks through the upper portion of the rocks from passing further down; and the frequent occurrence of springs just above a bed of clay on the side of a hill or cliff might thus be explained.

The fact that the clay when baked becomes porous and permeable by water might be briefly mentioned, and illustrated by pouring some drops of water on a brick. Then the necessity for coating earthenware vessels, which are intended to hold liquids, with a 'glaze,' or kind of glassy varnish, would be understood.

LESSON XXXIII.

GOLD AND GOLD-LEAF.

OBJECTS REQUIRED—*Gold coin; bright silver coin; sheet of iron; tinned iron; sheets of lead and copper; table-knife or key (bright); book with gilt-letters; (gilt picture-frame); gold-leaf mounted between sheets of glass; leaf of Dutch metal; piece of lead to be hammered; hammer; wooden block; rusty iron.*

ANALYSIS OF LESSON.

Recognise substance; its use and value.
Ex.—*Show gold coin.*

Silver has partly same properties and uses;—metals.
Ex.—*Show bright silver coin; compare with gold.*
Show sheets of iron, tinned iron, lead, and copper.

Gold (unlike iron, lead, &c.) retains its lustre.
Ex.—*Show bright iron, black iron sheet or nail; rusty iron; dull lead.*

Other characters of metals;—great weight of gold.
Ex.—*Compare weight of sovereign and shilling; note cold feeling.*

Gold leaf; use in gilding.
Ex.—*Show book with gilt letters, and gilt frame.*
Show mounted gold-leaf; look through towards light.
Show sheet of Dutch metal.

Means of producing sheets of clay; rolling of metal.
Ex.—*Show rolled sheets of metal.*
Flatten out lead by hammering.

Explain term 'malleable';—gold most malleable substance.

Describe briefly process of gold-beating.

Applications of other malleable metals; sheet-iron, lead, &c.

NOTES.

Subject of Lesson.—Malleability, as a marked character of certain solids, will perhaps be best considered with special reference to the most malleable of all substances—gold. There will, however, be an opportunity in the course of the lesson of considering briefly certain other notable characters of gold, as well as of noting the malleability of some other metals.

Show the children a gold coin; let them give its name, state its relative value, and name the substance of which it is composed. Let them name other articles made of gold; and also give, if they can, any reason for its being so highly valued—viz., in part because of its beautiful bright yellow colour, and also on account of its being comparatively rare.

Point out that another substance similar in many respects to gold, but different in colour, is used for coins and ornaments. Let them name the substance—silver—and compare the beautiful bright appearance of the two substances. Also let them state to what class of bodies these two substances belong (viz., metals), and name other substances belonging to that class, e.g., iron, tin, lead, copper, &c. Sheets of these last-mentioned metals should as far as possible be shown. Show them a clean knife or key as an example of perfectly clean bright iron; and point out how the iron when heated loses this bright surface, and becomes covered with a dull black coating (as seen on an ordinary iron nail, or on sheet iron); and how, when exposed to damp air, it becomes rusty. Many of the other metals also readily tarnish and become dull when exposed, e.g., lead. Gold, however, retains its beautiful bright lustre under most conditions; and this is another of its valuable characters.

See if the children can describe any other general characters of metals, besides their peculiar bright appearance, by which they may usually be recognised. (The comparatively great weight, and usual cold feeling when touched, were described in a previous course of lessons as being characteristic of most metals, and these might be again illustrated.) Let a child compare the weight of a half-sovereign with that of a sixpence, or a sovereign with a shilling; and tell them that gold is almost the heaviest metal known. Lead was said to be used on the plumb-line on account of its being a very heavy substance, but gold is very much heavier than a piece of lead of the same size.

Show them next a book-cover with large gilt letters, and if possible a gilt picture-frame, to illustrate other uses of gold. Tell them that for these purposes an exceedingly thin sheet of gold is used; and show them a sheet of gold-leaf mounted between two sheets of glass. Let the children examine the gold-leaf, and note the beautiful bright yellow colour of the surface; then let them hold it up to the light of the window or a candle-flame to observe that it is so very thin as to be really transparent. Objects may be seen through the gold-leaf, and the light which comes through the gold is of a peculiar bluish-green colour. (A leaf of Dutch metal—a variety of brass which admits of being made into thin sheets, but not nearly so thin as gold-leaf, and which is often used as a very inferior imitation of gold-leaf—might be shown as an illustration of a metal in the form of a very thin sheet. It has an advantage over gold-leaf for this purpose, in that it may be readily handled with ordinary care, whereas sheets of gold-leaf are too delicate to be taken in the hand.)

Remind the children of the flattening out of clay into a sheet in the last lesson, and let them describe how it was done. Show them sheets of iron, copper, and lead which have been produced by rolling. In some instances (iron, for example) the metal is heated before being rolled; let the children, if they can, explain the effect of heating it, viz., to make it softer. Hammer a piece of lead on a block of wood or stone, to show it being flattened out under the hammer. Tell them that substances which admit of being thus hammered or rolled out into thin sheets are often described as being 'malleable'; and write on the board a list of the malleable substances mentioned in the course of the lesson.

Then describe briefly the manner in which gold-leaf is made, as follows:—Some gold is first rolled out into a thin sheet, and then pieces cut from the sheet are placed between leaves of a thin, tough substance (known as 'gold-beater's skin'), and beaten for a long time with a heavy hammer.

Gold is said to be the most malleable metal; let them explain what is meant by that statement—viz., that it can be hammered out into the thinnest sheets without breaking. (The sheet of Dutch metal when held up to the light has a very different appearance from the gold-leaf, being full of very fine holes, through which white light may be seen to come, the metal itself not being thin enough to be transparent.)

Some of the applications of the other malleable metals referred to might be then briefly discussed, e.g. the working of red-hot wrought-iron under the hammer to form horse-shoes, shovels, &c.; the ordinary tinned-plate saucepans, kettles, plates, bread-tins, &c., made of rolled iron sheets coated over with tin to prevent them from rusting; the use of sheet lead on roofs, and often in tea-chests &c.

LESSON XXXIV.

SOLIDS, LIQUIDS, AND GASES.

OBJECTS REQUIRED—*Moist clay; india-rubber; large wood cube; methylated spirit; tumbler; brown paper for smoke; matches; benzoline; steel knife; blotting-paper; cork; sealing-wax; candle in candlestick; sheet of lead; water.*

ANALYSIS OF LESSON.

lassification of bodies into *fluids* and *solids*; distinguishing characters.

Ex.—*Children select fluids from substances on table; name other fluids.*
Fill inverted tumbler with smoke from paper; prove smoke a fluid.

Solids agree in not flowing; differ in many other respects.
Some solids yield more readily to pressure than others; *softer* and *harder*.

Ex.—*Press finger on clay, india-rubber, iron, wax.*

Examples of very soft and very hard bodies, and substances useful because hard; means of softening some.
Some solids recover themselves after yielding,—*elasticity*.

Ex.—*Illustrate with india-rubber, by bending, &c.*
Children find other elastic and non-elastic bodies, and prove.

Some solids yield considerably without breaking, others not,—*tough and brittle*.

Ex.—*Bend india-rubber backwards and forwards.*
Children select tough and brittle bodies.

Some allow of being hammered or rolled,—*malleable*; examples.
Some solids are very *porous*; effects of porosity.

Ex.—*Children select porous substances, and prove.*

Some solids *melt* easily, others very difficult to melt; examples.

Ex.—*Show melting of wax in burning candle.*

Differences between liquids and solids.
Result of heating liquids—vapours or gases.

Ex.—*Show benzoline evaporating from warm hand.*

Differences between gases and liquids; pressure (air).

NOTES.

Subject of Lesson.—It is proposed in this lesson to sum up generally the principal properties of bodies which have been studied in the preceding lessons, and to revise briefly the distinguishing characters of solids, liquids, and gases, and the relations between those forms of matter.

Place on the table a number of bodies which will illustrate the chief properties of substances studied in the preceding lessons, including two or more examples of liquids. Remind the children that in previous lessons certain substances have been spoken of as 'fluids;' let them select from the specimens on the table any that might be so described, explain clearly the meaning of the term, and apply it to the selected substances. Then let them name other fluids. If they do not themselves suggest certain gases, show them smoke from some smouldering paper under an inverted tumbler, let them give reasons for including it among the fluids, and name other similar bodies (coal-gas, &c.) Lead them to state clearly the distinguishing character of fluids. All substances omitted from the class of fluids agree in the fact that they do not flow when unsupported, and are considered as forming a natural group; let the children give the name for this group, viz., solids.

Set together a number of typical solids, point out that they do not flow, even though unsupported on all sides, and let the children explain the reason for this, viz., that the particles are firmly held together by the power which they have learnt to call cohesion. And for the same reason each of such bodies retains its special shape, so that we may have, lying on the table, solid bodies with the form of thin sheets, cubes, rods, or with any other form.

But though solids all agree in having these special characters, they differ among themselves in other respects, as has been shown in the preceding lessons. Thus some yield readily when pressed upon (press upon moist clay, india-rubber, &c.), others resist or withstand an ordinary pressure (press upon a block of wood, piece of iron, stick of sealing-wax). Ask the children to say how they would describe this difference (viz., some would be said to be *softer* or *harder* than others), to name some very soft and some very hard bodies, and to describe how they would proceed to test the relative hardness of substances. Let them name some substance useful to us on account of its hardness, and state some of its applications. They might also be asked to explain how in many cases hard substances may be made softer (viz., by heating them), and to give examples.

Next remind them that some solid bodies, after yielding to the force (bending, twisting, &c.), readily recover their original shape. Illustrate this by means of the india-rubber, and let the children give the name for this property,—*elasticity*. Let them select other examples of elastic bodies, and some of bodies that are practically devoid of this character.

Then show them that the india-rubber may be bent backwards and forwards several times without breaking; let the children select other solids which will admit of this treatment, and others again which break across when bent or struck. Let them give the names used to express these characters, viz., *tough* and *brittle*.

In connection with the toughness of bodies, remind them that some substances may be hammered or rolled out into very thin sheets. Let them give examples of such *malleable* substances.

Some solids, again, were found to contain numerous small holes or pores, which rendered them comparatively light, and in many cases permeable by liquids. Let the children select examples of such *porous* bodies, and state briefly how the porous character might in each case be demonstrated.

Lastly, some solids were found to *melt* very readily, while others were very difficult to melt. Illustrate melting by pointing to the wax in a burning candle; let the children explain what is meant by melting, and what causes the change from solid to liquid. Ask them to give other examples of melting which they have seen. (See that they give actual examples of melting by heat, and not of solution.)

Then let them describe how *liquids* (e.g., those substances produced by melting solids) differ from solids, and explain why it is necessary to enclose them in vessels. Lead them to describe clearly the *horizontal* surface of liquids at rest, and the use of the spirit-level for testing the horizontality of surfaces.

Ask them to describe the effect of heating liquids—viz., their conversion into *vapours* or *gases*. Pour some benzoline on the hand to illustrate this process of evaporation; and lead them to describe the differences between vapours (or gases) and liquids. In connection with the indefinite expansion of gases, lead them to describe the pressure of the gas against the enclosing vessel, and pass from this to the constant pressure of the air against all surfaces with which it is in contact.

LESSON XXXV.

A SUNDIAL.

OBJECTS REQUIRED—*Mounted compass-needle; board (about one foot square), with hole in centre for rod; brass (stair) rod; candle in candlestick; matches; sheet of glass; slate.*

ANALYSIS OF LESSON.

Phenomena of burning candle; radiation of light.

Transparent and opaque bodies.

Ex.—*Let light from candle or sunlight fall on glass and slate.*

Opaque bodies cast shadows; cause and position of shadow.

Ex.—*Show shadow from rod or slate in sunlight or candlelight.*

Show your own shadow when light in front, on right, &c.

Note shadows of window-bars, boards, &c.

Source of daylight.

Shadows cast by sunlight move; cause.

Ex.—*Mark position of shadow or bright patch; note after interval.*

Observed position of sun at noon, 6 A.M., 6 P.M.

Ex.—*Children point out position of sun at noon, morning, and evening.*

Construction of simple sundial.

Ex.—*Set up rod on board; draw line from rod towards North found by compass; mark XII.*

Draw East and West lines on board and mark VI.

Place candle in position to cast shadows on lines; or note actual position of shadow cast by sunlight.

Board shows correct time in this position only.

Uses and varieties of sundials; disadvantages.

NOTES.

Subject of Lesson.—The subject of the measurement of space having been studied in preceding lessons, it is proposed in the last two lessons of this series to consider in the same elementary manner some of the principles connected with the measurement of time, so far at least as this may be illustrated by the phenomena of day and night and the sundial. In the present lesson the principle of action of the sundial is studied.

Commence the lesson by questions about a candle,—about the phenomena attending its burning, the object of burning candles, what comes from them, from which part the light and heat come, in which direction the light passes, what it falls upon, &c.

Then question the children as to the different behaviour of bodies upon which light falls: how some allow the light to pass through them and are said to be transparent, while others stop it and are said to be opaque. Illustrate this by reference to a sheet of glass and a slate.

The effect of opaque bodies in casting shadows should next be discussed, e.g., the cause of the shadow (viz., the exclusion of light from that part), and its position with respect to the position of the source of light and the opaque body (viz., on the side opposite to the light). These facts might be illustrated by means of the candle (letting the shadow fall on the wall or on a white sheet of paper or cardboard) in a somewhat darkened room. The position, also, of your own shadow when the candle is behind you, or on your right, &c., should be described by the children (and illustrated if necessary), and the effect on the shadow of moving the light described. (If the lesson were given in a room into which the sun was directly shining, the illustrations might be so modified as to use the sunlight for casting the shadows.)

The fact that candles are used only in the absence of sufficient daylight should then be noted, and the source of 'daylight' described. A number of bodies which are observed to cast shadows in sunlight should be named, and if possible certain shadows in the room (of rods, window-bars, boards, &c.) pointed out and traced to the opaque bodies by which they are caused. Let the children state whether the shadows of fixed bodies cast by sunlight are always to be seen in the same place, and also whether the bright patches of light caused by the sun shining through a window or opening into a room are always on the same part of the wall or floor. Ask the children to explain the cause of this change in position, viz., the apparent movement of the sun. (If the sun is shining into the room, the position of some particular shadow or bright patch should be marked, then again examined after an interval of a few minutes, and the direction of the sun's motion pointed out.)

The fact that the sun is seen in different positions at different parts of the day should be clearly understood, and the children led to point out, if possible, its observed position at midday (or noon), in the morning, and in the evening. They should learn that the sun is always (in this country) in the south at noon, and that when seen at six o'clock in the morning it is in the east, and at six o'clock at night in the west.

Set a rod upright on a board lying on the floor or table, and say that you wish to mark on such a board the position which the shadow of the rod would occupy at various times if the sun could shine on it. (Set it in the sunlight if possible.) Let the children state in which direction the shadow would point at noon (viz. towards the north), and by means of a compass needle find the north and draw a line on the board from the rod towards the north, marking it XII. Similarly let them find the position of the shadow at 6 A.M. and 6 P.M., and draw the lines on the board, marking them with their proper numbers.

Point out that the lines so marked would not be correct if the board were turned or laid in any other position; the line of the shadow at noon must always point to the north. (A burning candle might be placed so as to cast the shadow successively in these directions, or if the board were in direct sunlight the position of the actual shadow with reference to the lines should be noted.)

Then the division of the intermediate spaces into six parts to indicate the hours, and the division of these into half-hours, &c., might be explained; and the use of such a simple 'sundial,' to show the time approximately, described. (The children might be encouraged to make some such simple arrangement for themselves, in the yard, or on the ledge of a south window close to an upright bar, marking the hour lines by reference to a clock.)

They might be told that sundials were formerly very much used, before clocks and watches were known; that various kinds can be made—some of them set horizontally on pillars, and others of somewhat different construction to hang upon walls—but all of them having some projecting rod or plate to cast the shadow. They should be led to describe a disadvantage of such instruments for the purpose of time measurement, viz., the fact that they are useless in the absence of sunlight.

(NOTE.—It should be remembered that the time shown by a sundial does not always agree exactly with that shown by a clock, and also that our clocks show Greenwich time and not local time.)

LESSON XXXVI.

DAY AND NIGHT.

OBJECTS REQUIRED—*Mounted globe; candle in candlestick; matches; compass (or circle with cardinal points marked).*

ANALYSIS OF LESSON.

Question on sundial and position of sun at stated times.

Apparent revolution of sun through sky; direction and period.

Measurement of intervals by recurrent phenomena; beats in singing, &c.

Earth a great globe or sphere.

Ex.—*Show large school globe; represent apparent motion of sun by candle.*

One hemisphere only seen or illuminated at one time; day and night.

Ex.—*Let children view globe from various positions.*
Let sunlight or candle-light fall on various parts of globe.

Rotating globe and fixed source of illumination, and *vice versâ.*

Ex.—*Carry lighted candle round globe, and round child at rest.*
Let child turn round near candle at rest.
Rotate globe, with point marked, near candle at rest.

Earth rotates steadily; compare effects with objects seen from moving railway carriage.

Direction of earth's rotation learnt from motion of sun and stars.

One complete rotation brings sun (stars, &c.) to same point again; noon to noon measures day.

Sun's apparent motion from E. to S. or S. to W. measures quarter rotation (day).

Ex.—*Show compass or card with cardinal points.*

Division of day into hours, minutes, and seconds.

Unequal periods of daylight; sun always south at noon.

NOTES.

Subject of Lesson.—The principle of measuring time by the apparent motion of the sun through the sky was studied in the last lesson in connection with the indications of the sundial. We have now to show that this apparent motion of the sun is due to the actual motion of the earth, the rotation of which causes the alternation of day and night, and marks those natural periods of time which we call days.

Ask the children to name the instrument studied in the last lesson, to describe the manner in which the time was indicated, what gave rise to the shadow, and in what direction the shadow would point at noon, at 6 A.M. and 6 P.M. respectively. Trace the course of the sun through the sky from E. through S. to W. Compare it to the hand of a clock, or to something moving round the walls of the room, and explain that when it comes back again to the point whence it started we say it has made a complete revolution.

If the sun moves round regularly, each time it comes to the south again will mark a certain period or interval, by which we can check our clocks to see if they keep correct time. This method of measuring time by the regular recurrence of certain events might be illustrated by reference to the determination of intervals by counting the ticks of a clock, the number of swings of a pendulum, or the beats of the hand or pointer in singing.

Remind the children that geography teaches us that our earth is a great globe or sphere, round which the sun seems to travel, and that when the sun sets to us it is passing round to the other side of the ball out of our sight. Illustrate this by means of a large globe and candle.

Then show by means of the globe in strong sunlight (or by a single gaslight or candle flame in a darkened room), that only half the globe (one hemisphere) can be illuminated at once, just in the same way as we can only see half the globe at any one time. That half of the globe upon which the sun shines at any given time has daylight, while the other hemisphere has its night. This might be illustrated by carrying a candle round a globe, and also round a child standing at rest in the middle of the room, all sides of the body in turn being illuminated.

Next show that the same effects, as in the last case, are produced if the candle is at rest on the table and the child turns round in front of it, the side towards the candle being illuminated and the opposite side being always in the shadow. Turn the globe round while the candle stands near it (the flame being on a level with the centre of the globe as nearly as possible), showing that each part in turn is illuminated, and that any particular point (stick a small piece of paper on one part) performs part of its journey in the light and part in the darkness.

Tell them that for several reasons people have been brought to believe that the sun (like the candle in the last experiment) practically stands still, while the great globe on which we live turns round. We ourselves, like the piece of paper in the experiment, are therefore carried round, and are for part of the time in the light of the sun (day), and for part of the time in the shadow (night). Remind them of the way in which objects seen through the window of a railway carriage seem to move past us in the opposite direction to that in which we ourselves are really moving; and that if the carriage moved very steadily indeed, so as not to shake us, we might think we were at rest and that the outside objects were moving. And as the earth really moves round very steadily (though very quickly), we do not even know that we are moving at all until we look right away to the sun or the stars, and then we see that they all appear to be in motion in one direction. The direction in which the earth moves will be opposite to that in which these bodies appear to move; that is to say, as they seem to move from E. to W., the earth must be moving and carrying us from W. to E.

Then show again the experiment with the piece of paper on the rotating globe, and point out that we know that when the paper comes back again to the same position the globe has turned round once. Lead the children to understand and explain that, if we see the sun in the south to-day at a certain time, the earth must turn completely round once before we can see the sun again in the same position. So that the earth turns round once in that space of time which we call a *day*—say from one noon to the next. Point out also by reference to a compass, or a circle having the cardinal points marked on it, that E. and W. are each a quarter of the way round from S.; so that the earth makes a quarter turn from 6 to 12 o'clock, or from 12 to 6. The earth therefore measures days for us by its rotation.

Speak briefly of the division of the day (as distinguished from the period of daylight) into twenty-four hours, and the division of hours into minutes and seconds, by means of such instruments as sundials and clocks.

The unequal length of the period of daylight (day and night as usually understood) at different parts of the year, may on the present occasion be simply explained by reference to the earlier and later rising and setting of the sun. But it should be clearly understood that, no matter at what time the sun may rise or set, at noon it is always in the south. And this fact, as well as the alternation of day and night, is due to the regular and steady manner in which the earth constantly turns round.

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